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State of Illinois
Department of Registration and Education
STATE GEOLOGICAL SURVEY DIVISION
John C. Frye, Chief

GUIDE LEAFLET

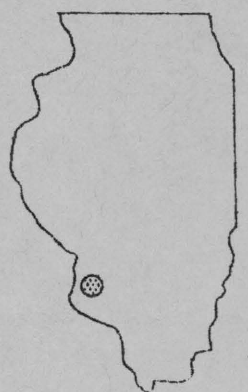
GEOLOGICAL SCIENCE FIELD TRIP

Sponsored by
ILLINOIS STATE GEOLOGICAL SURVEY, URBANA

MILLSTADT - DUPO AREA

St. Clair and Monroe Counties

French Village, Cahokia, Columbia, and Millstadt 7.5-minute Quadrangles



ILLINOIS STATE
GEOLOGICAL SURVEY
LIBRARY

Leaders
William E. Cote, David L. Reinertsen, George M. Wilson, Myrna M. Killey
Urbana, Illinois
April 18 & October 10, 1970

TO THE PARTICIPANTS:

The Geological Science Field Trip program is designed to acquaint Illinois residents with the landscape, the rock and mineral resources, and the geological processes that have led to their origin. With this program, we hope to stimulate a general interest in the geology of Illinois and a greater appreciation of the state's vast mineral resources and their importance to the over-all economy.

We encourage you to ask the tour leaders any questions that may occur to you during the trip. Discussion often clarifies points that otherwise would remain confused to many of the participants. We also invite your written comments upon the conduct of the trips so that we might improve them as much as possible.

Additional copies of this guide leaflet, as well as itineraries for field trips that have been held in the past, may be obtained free of charge by writing to the Illinois State Geological Survey. The itinerary maps for each field trip can be purchased for 10 cents each.

Several of the stops along this itinerary are located on private property whose owners have graciously given us permission to visit their lands. Please obey the instructions of your trip leaders and conduct yourselves in a manner that will show respect for the property owners' cooperation. Please do not litter, or climb on fences, and leave all gates as found, so that we may be welcome to return on future field trips. These simple rules of courtesy also apply to public property as well. For the convenience of those persons who may use this itinerary at some future time, the names and addresses of every private property owner are listed for the respective stops on a page at the back of this guide leaflet. Whenever possible, always attempt to obtain permission when visiting private property.

We hope that you enjoy today's field trip and will attend others in the future.

THE STAFF
EDUCATIONAL EXTENSION SECTION
ILLINOIS STATE GEOLOGICAL SURVEY

MILLSTADT-DUPO GEOLOGICAL SCIENCE FIELD TRIP

INTRODUCTION

Geologic Setting

The Millstadt-Dupo area is located near the bluffs of the Mississippi Valley in adjacent parts of St. Clair and Monroe Counties in southwestern Illinois. The area is quite complex geologically and presents a variety of interesting geologic and physiographic features. The broad, deep flat-bottomed Mississippi Valley is the most prominent topographic feature. It contrasts sharply with the deeply dissected, undulating upland to the east. Steep, spectacular bluffs cut in massive Mississippian limestone formations rise abruptly to heights of more than 200 feet above the valley floor. The upland, where these limestone formations form portions of the bedrock surface, exhibits some of the best-developed sinkhole topography in Illinois.

The field trip area occurs at the southwestern edge of the glaciated region of Illinois. It was covered all or in part by glaciers during both the Kansan and Illinoian glaciations, the second and third of the major glacial intervals of the Ice Age. Drift of Illinoian age, deposited between about 250 and 200 thousand years ago, is exposed in many places on the upland. The last, or Wisconsinan glacier, did not reach the Millstadt-Dupo area, but thick outwash deposits of this glaciation occur in the Mississippi Valley. Wisconsinan loess also thickly blankets the valley bluff and the upland, forming the surficial material throughout the area.

The glacial deposits are underlain by approximately 4,000 feet of much older, consolidated sedimentary bedrock formations (fig. 1). These formations consist mainly of sandstone, shale, and limestone that were deposited layer by layer in the ancient shallow seas that invaded the midcontinent region during the Paleozoic Era, between 550 and 270 million years ago. The strata are divided into major subdivisions known as systems, each of which was deposited during a specified period of geologic time. Approximately the uppermost 1,000 feet of these sedimentary rocks, belonging to the Mississippian and Pennsylvanian Systems, are exposed in the field trip area (fig. 2). Older formations of Devonian, Silurian, Ordovician, and Cambrian ages are known from deep oil wells which penetrate them. The base of the Cambrian strata rests upon an ancient basement of Precambrian igneous and metamorphic rocks that are more than one billion years old.

Geologically the Millstadt-Dupo area is situated at the southwestern margin of the Illinois Basin, a large spoon-shaped bedrock structure that underlies most of Illinois and adjacent parts of Indiana and Kentucky (fig. 3). Regionally the strata in the field trip area are gently tilted down to the east into the basin. Westward they rise onto the Ozark Dome, a broad domal uplift in southeastern Missouri (fig. 4). The older Paleozoic formations and the Precambrian rocks that are buried in the field trip area rise to the bedrock surface on the dome. As the Illinois Basin was forming during the Paleozoic Era, it was gradually filled with the Paleozoic sedimentary rocks. Toward the deepest part of the basin in extreme southeastern Illinois, the Paleozoic rocks thicken to more than 13,000 feet.

The regional tilt of the Paleozoic strata in the field trip area is interrupted by a sharp upfold or arch of the bedrock called the Dupo Anticline (figs. 2 and 4). This anticline crosses the area from north to south, trending slightly west of north. Excellent exposures of strata tilted as steeply as 50 degrees afford one of the best opportunities in Illinois to examine the results of crustal folding. The entire anticline is continuously exposed in cross section in the steep bluff near Dupo. The anticline is the site of the Dupo Oil Field which has been producing

SYSTEM	SERIES	GROUP, STAGE	FORMATION, MEMBER	ROCK TYPE	THICKNESS	DESCRIPTION
QUAT.		Recent				Sand, silt, clay
QUAT.	Pleist.	Wisconsinan	Peoria			Loess, sand and gravel, silt
QUAT.	Pleist.	Wisconsinan	Roxana			Loess, sand and gravel, silt
QUAT.	Pleist.	Illinoian				Till, some outwash
PENNSYLVANIAN		McLeansboro			25	Siltstones, shales, limestones, coals, underclays
PENNSYLVANIAN		Kewanee	Carbondale: No. 7 Coal, Conant Ls., Brereton Ls., No. 6 Coal, No. 5 Coal, Hanover Ls., No. 4 Coal, No. 2 Coal		200	Sandstones, siltstones, shales, limestones, coals, underclays
PENNSYLVANIAN		McCormick			50	Sandstones, siltstones, shales, thin coals, limestones rare
MISSISSIPPIAN	Chesterian		Cypress		50	Sandstones, shales, limestones; thin coals rare in upper part; red beds
MISSISSIPPIAN	Chesterian		Ridenhower		30	
MISSISSIPPIAN	Chesterian		Bethel		20	
MISSISSIPPIAN	Chesterian		Downeys Bluff		10	
MISSISSIPPIAN	Chesterian		Yankeetown		10	
MISSISSIPPIAN	Chesterian		Renault		30	
MISSISSIPPIAN	Valmeyeran		Aux Vases		50	Sandstone
MISSISSIPPIAN	Valmeyeran		Ste. Genevieve		80	Limestone, oolitic, some chert
MISSISSIPPIAN	Valmeyeran		St. Louis		245	Limestone, some dolomite, some chert
MISSISSIPPIAN	Valmeyeran		Salem		80	Limestone, some oolites, some chert
MISSISSIPPIAN	Valmeyeran		Ullin		65	Limestone, some chert
MISSISSIPPIAN	Valmeyeran		Warsaw		25	Shale
MISSISSIPPIAN	Valmeyeran		Keokuk		60	Limestone, very cherty
MISSISSIPPIAN	Valmeyeran		Burlington		100	Limestone, very cherty
MISSISSIPPIAN	Kind.		Fern Glen		60	Limestone, some chert, shale
MISSISSIPPIAN	Kind.				30	Limestone and shale
DEV.		New Albany			15	Shale
SIL.					75	Dolomite, cherty
ORDOVICIAN	Cin.	Maquoketa			150	Siltstone, shale, some limestone
ORDOVICIAN	Cham.	Kimmswick			100	Limestone
OLDER ORDOVICIAN AND CAMBRIAN STRATA					2450	Limestone, dolomite, sandstone, shale
PRECAMBRIAN						Granite, other igneous and metamorphic rocks

Fig. - 1 - Generalized geologic column of strata in the Millstadt-Dupo area.

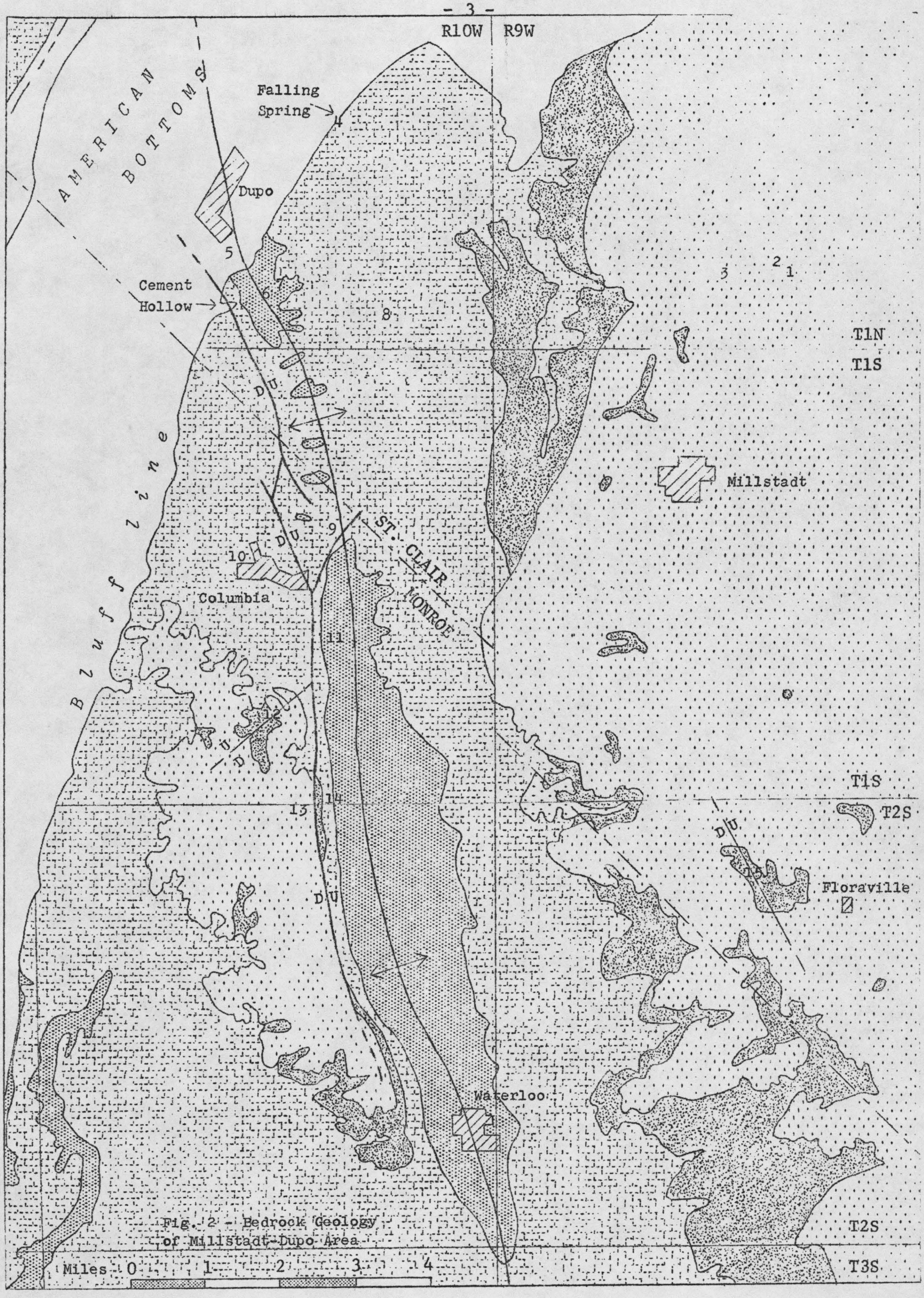


Fig. 2 - Bedrock Geology of Millstadt-Dupo Area

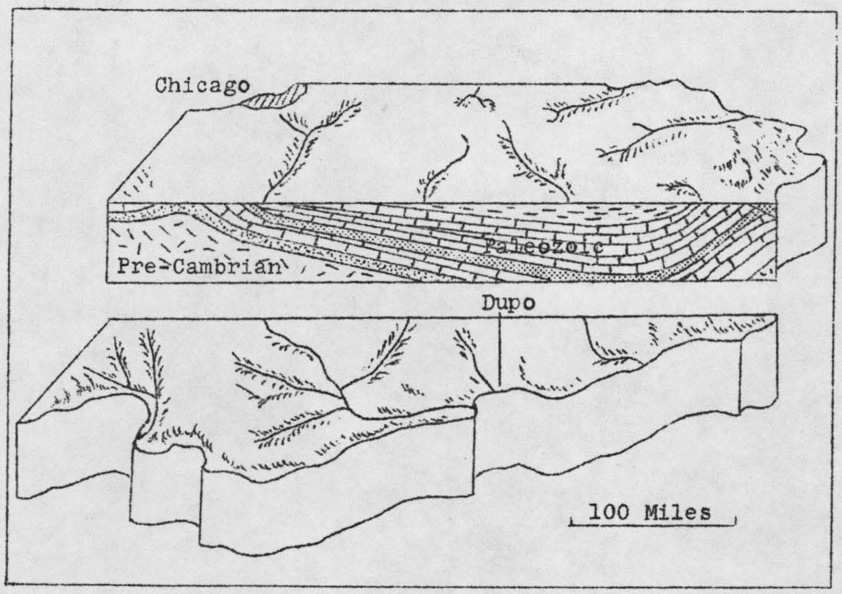


Fig. 3 - North-south cross-section through Illinois showing the Paleozoic strata in the Illinois Basin.

crude oil from Ordovician rocks for nearly 50 years. Other important mineral resources that are being exploited in the field trip area include coal from the Pennsylvanian strata, groundwater from glacial outwash in the Mississippi Valley, and crushed stone from the Mississippian limestones.

Glacial History of Illinois

During the Pleistocene Epoch, commonly referred to as "The Great Ice Age," an extensive continental ice cap developed in the northern hemisphere during times when the mean annual temperatures were a few degrees cooler than they are now. The portion of the ice cap that intermittently covered northern North America has been named the Laurentide Ice Sheet. Beginning about 1 million years ago and ending only 5,000 years ago, southward expansions of the ice sheet caused four major glacial invasions of Illinois and the Midwest. The ice that entered Illinois came from centers in central and eastern Canada. Each of the four major glacial advances were followed by long, warm interglacial intervals during which the glaciers melted completely away (see attached Pleistocene Time Table). During these intervals, the deposits left by the glaciers eroded and weathered. Each of the glacial advances produced significant changes in the topography and drainage of the glaciated areas. In order of occurrence, the glaciations of the Midwest have been named the Nebraskan, the Kansan, the Illinoian, and the Wisconsinan (fig. 5). The names are derived from the states where glacial deposits of these ages are best developed or were first described. The last glacier, the Wisconsinan, melted from northeastern Illinois a mere 10,000 years ago.

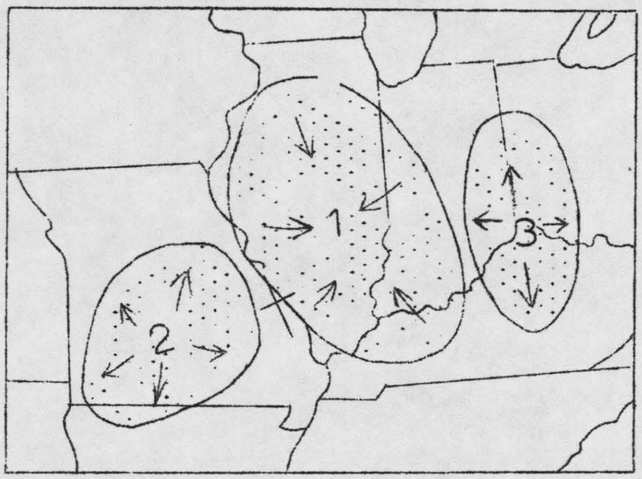


Fig. 4 - Index map showing the location of (1) Illinois Basin, (2) Ozark Dome, and (3) Cincinnati Arch.

The Pleistocene glaciers profoundly modified the landscape of Illinois. They transported vast amounts of rock and soil debris that was eroded from the areas over which they moved. As the glaciers advanced and later melted back, these materials, known as drift, were deposited. Within the areas that were covered by the ice, there are extensive surficial deposits of ice-laid material called till. Areas that were covered several times by glaciers may have more than one layer of till. Till is an unsorted, unstratified mixture of all sizes of rock debris that generally has the consistency of pebbly clay. Numerous arcuate till ridges called end moraines were formed at the margin of the Wisconsinan glacier in northeastern Illinois (see Glacial Map of Northeastern Illinois). Each end moraine represents an

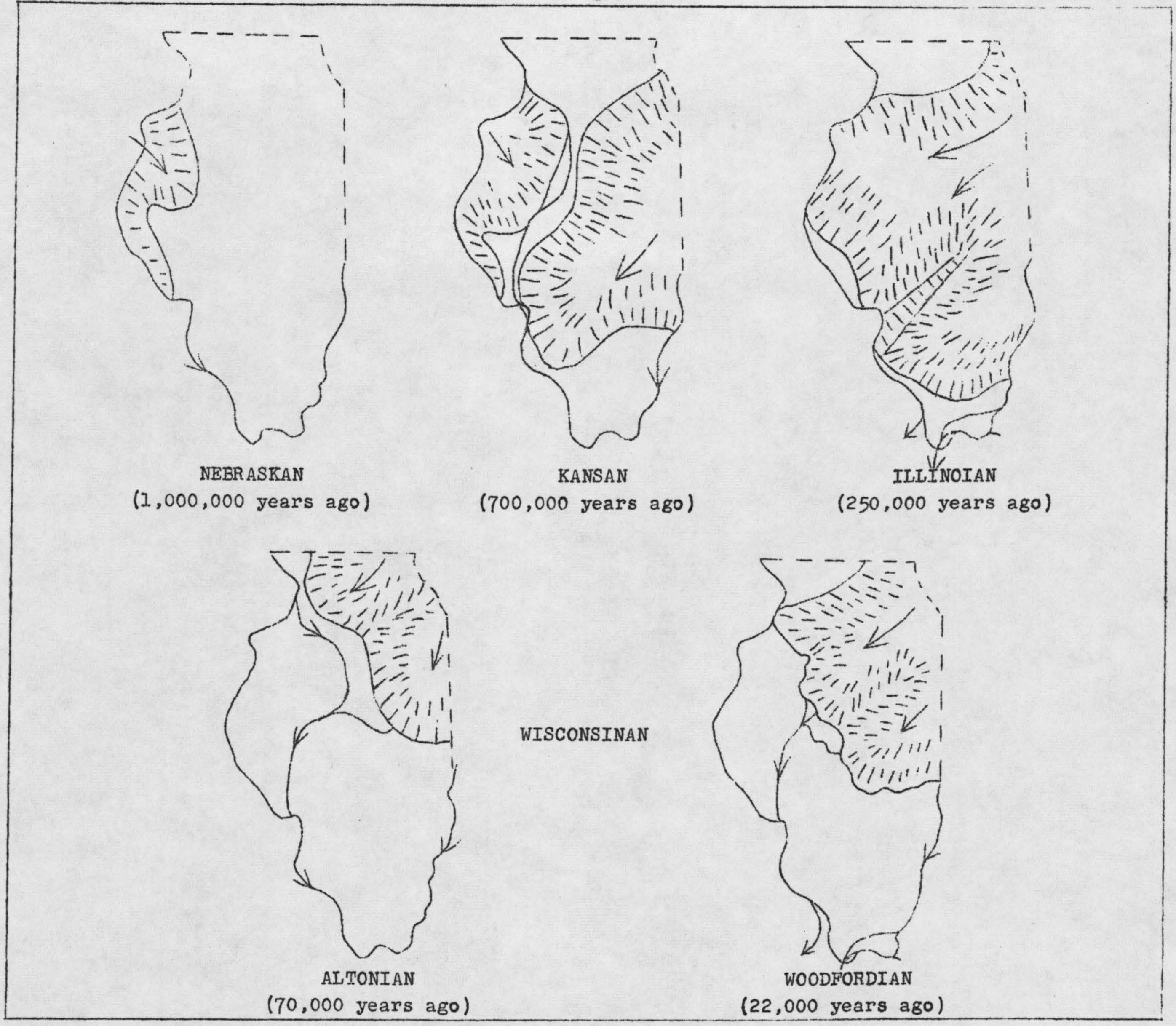


Fig. 5 - Sketch maps showing the extent of the major glacial advances into Illinois during the Pleistocene Epoch. Approximate times of invasion are given. Two substages--the Altonian and the Woodfordian--of the Wisconsinan Stage are shown. Arrows indicate the directions of ice movement and flow in major drainage channels which drained the ice front.

advance of the glacier and a line along which the ice margin maintained a temporary fixed position. The moraines were built up by rock debris carried forward to the melting ice front. Thinner deposits of till that form gently undulating plains between the end moraines are known as ground moraines or till plains.

Sorted and stratified water-laid materials known as outwash, consisting of clay, silt, sand and gravel, were also deposited as a result of the glaciations. Outwash sediments were deposited by debris-laden meltwaters flowing away from the ice fronts during both the advances and retreats of the glaciers. Near the glacial margins, where meltwater was often not confined to definite channels, the outwash was laid as thin blanket-like deposits called outwash plains. Glacial lakes formed by the ponding of meltwater in valleys, in low areas on till plains and behind end moraines were also the sites of deposition of the finest outwash sediments. Outwash deposits were often overridden by the advancing glaciers, so that the drift deposits typically consist of interstratified layers of till and outwash. There is also interfingering of these materials laterally.

River valleys, such as the Mississippi, Illinois, and Ohio, provided major channelways for escaping meltwaters. These valleys were greatly widened and deepened in the bedrock during times of greatest meltwater floods. When the floodwaters were waning, the valleys were partially filled with outwash far beyond the ice margins. The outwash deposits, consisting largely of sand and gravel, are known as valley trains. For example, along much of its length, the valley train of Mississippi Valley is more than 200 feet thick. Many former river valleys in areas covered by the glaciers were completely filled and buried by glacial deposits. The meltwaters also cut new valleys and caused numerous changes in the drainage system, some temporary and some permanent.

Deposits of wind-blown silt, called loess, which form the surface materials over most of Illinois, are also the result of glaciation. The silt was blown from floodplains of the valley trains. Most loess deposition occurred in the fall and winter seasons, when colder conditions caused meltwater floods to recede, exposing the surfaces of the valley trains and permitting them to dry out. During Pleistocene time, as now, the winds prevailed westerly, and as a result, the loess deposits are thickest on the east sides of the source valleys. The loess thins rapidly away from the valleys. The loess is as much as 100 feet thick on the east bluff of the Mississippi Valley near Collinsville, just to the north in Madison County. The valley train of the Mississippi Valley was the principal source of loess for the Millstadt-Dupo area.

Depositional History of the Mississippian Sedimentary Rocks

Valmeyeran (middle Mississippian) formations consisting predominantly of thick limestones form the bedrock surface over most of the Millstadt-Dupo area (fig. 2). Chesterian (upper Mississippian) formations, which are exposed less extensively, consist of limestones, sandstones, and shales, with the sandstones and shales dominant. These formations form part of a thick section of Mississippian strata which occur in the upper Mississippi Valley. The Mississippian rocks in this region have a total cumulative thickness of 2,000 to 2,500 feet and form the type section for which the Mississippian System of rocks was named.

During Mississippian time, between 350 to 310 million years ago, the mid-continent of North America was a generally low-lying, stable platform. Clear, warm, shallow seas invaded the region, and the Mississippi Valley remained almost continually submerged throughout the Mississippian Period. During the middle part of the period the sea reached far to the north, and little sand and mud was carried into the basin. The relatively pure Valmeyeran limestones, including the Salem, St. Louis, and Ste. Genevieve Limestones, were deposited over enormous areas on the continental platform. The sea in which these limestones were deposited was fairly shallow, probably only a few hundred feet deep generally, and in many areas only a few tens of feet. Marine animals found the shallow seas ideal for their development. Some of the limestones consist almost entirely of cemented fossil fragments, or oolites, reflecting the shallow, wave-swept conditions of deposition.

Throughout Mississippian time the Illinois Basin was a slowly subsiding (sinking) region, flanked on the east and west by structurally high, or positive, areas--the Ozark Dome and the Cincinnati Arch. These higher areas supplied little sand and mud to the Illinois Basin, and most clastic sediments were carried into the basin from land areas far to the north and northeast in what is now Canada by an ancient river system called the Michigan River.

Near the end of Valmeyeran time the sea became more restricted in extent and the shoreline shifted southward. Increased amounts of sand and mud were delivered into the Illinois Basin by the Michigan River. Thin shales and sandstones in the upper part of the Ste. Genevieve Limestone indicate the depositional changes that were taking place. The overlying Aux Vases Sandstone records a great increase in the amount of sand that wes deposited in the nearshore areas of the Mississippian sea.

During the latter part of the Mississippian Period much greater amounts of sand and mud were carried into the sea by the Michigan River. A great delta was built out into the sea. This delta was very much like the present-day Mississippi River delta in Louisiana. As the Illinois Basin subsided slowly and as the amounts of sand and mud carried into the sea fluctuated, the extensive front of this delta oscillated northward and southward for hundreds of miles.

The fluctuating shorelines, shifting delta distributaries, and the continually changing water depths produced the striking vertical and lateral lithological variations that can now be seen in the Chesterian formations. Regular alternations of sandstone-shale and limestone formations were formed, each alternation beginning with deposition of basal sandstone and shale followed by deposition of limestone. Sandstones and shales record times when the delta front extended far out into the basin. Limestones indicate times when the shoreline was farther away. In some respects the sediments on the Chesterian Series resemble the cyclothems of the Pennsylvanian System, which overlies the Mississippian rocks in much of Illinois (see discussion below).

Some of the Chesterian limestones are very pure, but some are quite argillaceous (clayey) and sandy. Generally, the Chesterian sea was very shallow. Crossbedding and oolitic zones are common in the limestones, as are zones consisting of a hash of fossil remains that were broken by wave action. Sedimentary features such as pebbly zones, ripple marks, and cross-bedding are present in the sandstones, many of which are distributary and river channel sands. Thin coal seams associated with some of the sandstones indicate times when the sea withdrew temporarily and plant debris accumulated in fresh-water swamps. These late Mississippian coal swamps were forerunners of those that occurred more extensively later during Pennsylvanian time.

Sedimentary History of the Pennsylvanian Rocks

Pennsylvanian strata form the surficial bedrock in the eastern part of the field trip area. A large isolated patch of Pennsylvanian rocks are also preserved in a shallow synclinal area just to the west of the Dupo Anticline between Columbia and Waterloo (fig. 2). This syncline has been called the Columbia Syncline.

At the close of the Mississippian Period about 310 million years ago, the Mississippian sea withdrew from the midcontinent region. A long interval of erosion took place during early Pennsylvanian time. This erosion removed hundreds of feet of the Chesterian strata, completely stripping them away and cutting into older rocks over large areas of the Midwest. An ancient river system, descendant of the Michigan River, cut deep channels into the bedrock surface. Erosion was interrupted by the invasion of the early Pennsylvanian sea.

Depositional conditions in the Illinois Basin during the Pennsylvanian Period were similar to those that existed during late Mississippian time. The Pennsylvanian river system flowed southwestward across a low, swampy lowland, carrying

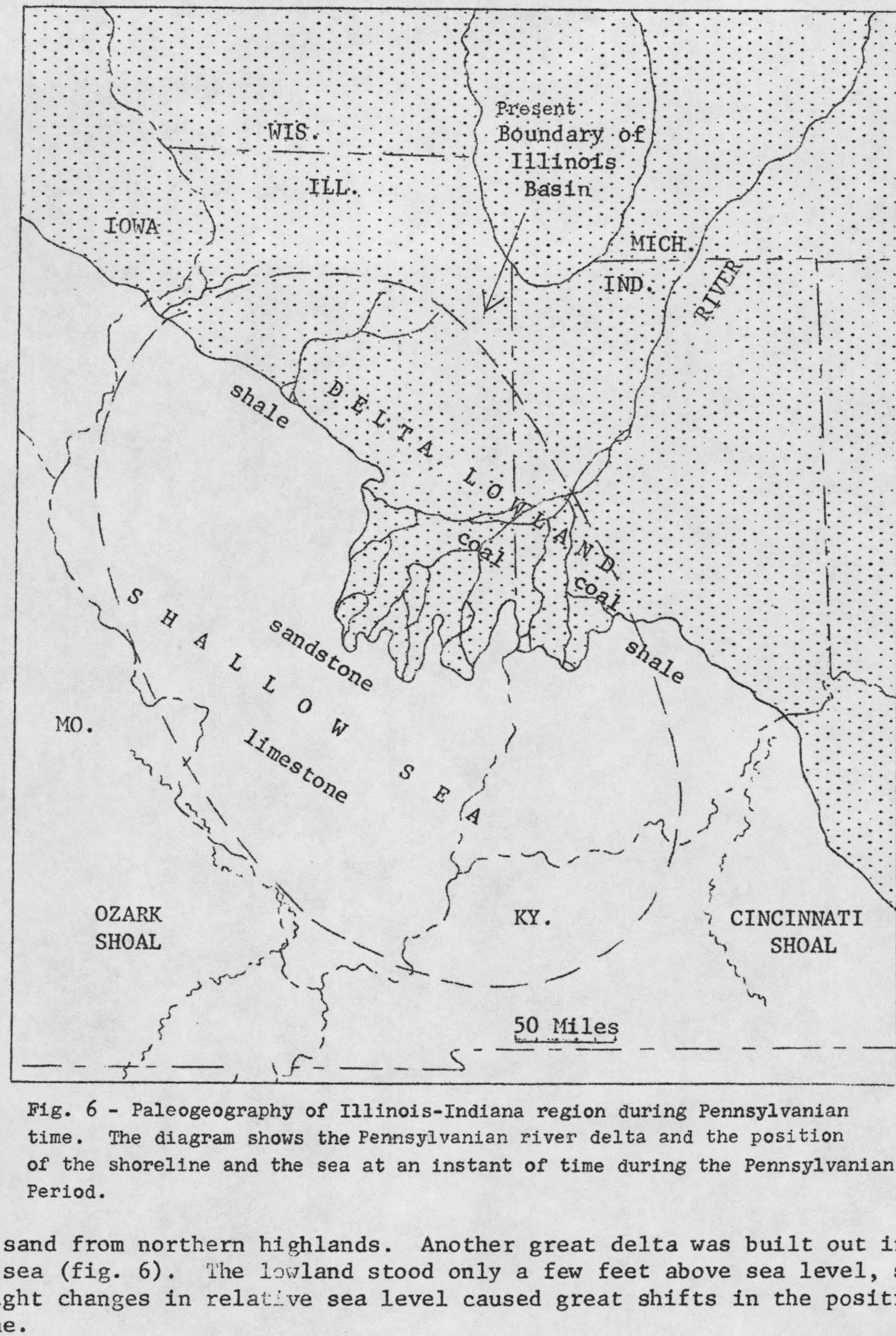


Fig. 6 - Paleogeography of Illinois-Indiana region during Pennsylvanian time. The diagram shows the Pennsylvanian river delta and the position of the shoreline and the sea at an instant of time during the Pennsylvanian Period.

mud and sand from northern highlands. Another great delta was built out into the shallow sea (fig. 6). The lowland stood only a few feet above sea level, so that only slight changes in relative sea level caused great shifts in the position of the shoreline.

Throughout Pennsylvanian time the Illinois Basin continued to subside. As during Chesterian time, the delta front continually shifted northward and southward due to worldwide sea level changes, intermittent subsidence of the basin, and variations in the amounts of sediment carried seaward from the land. The areas of land and sea continually changed as the shoreline shifted northward and southward. These alternations between marine and nonmarine conditions were more drastic and frequent than during Chesterian time, producing the even more striking lithologic variations in the Pennslyvanian rocks.

Conditions at various places on the shallow sea floor favored the deposition of sandstone, limestone, or shale. Sandstone was deposited near the mouths of distributary channels. These sands were reworked by waves and spread as thin sheets near the shore. The shales were deposited in quiet water areas--in delta bays between distributaries, in lagoons behind barrier bars, and in deeper water beyond the nearshore zone of sand deposition. Limestone, which formed by chemical precipitation from the sea and the accumulation of limy shells of marine plants and animals, was usually deposited farther from shore than the sandstone and shale, but some limestone was formed in nearshore areas where little sand and mud were being deposited. The areas of sandstone, shale, and limestone deposition continually changed as the position of the shoreline changed and as the delta distributaries extended seaward or shifted their positions laterally along the shore.

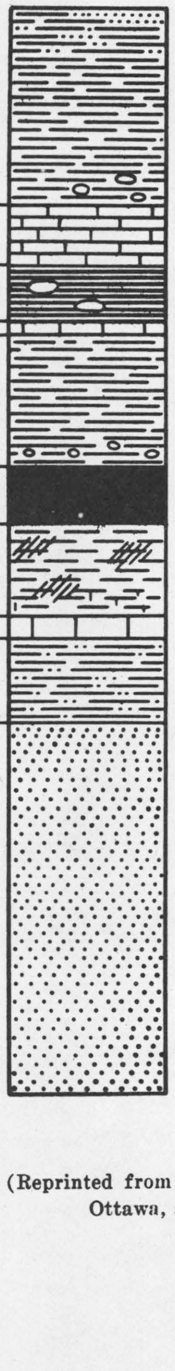
Nonmarine sandstones, shales, and limestones were deposited on the deltaic lowland bordering the sea. The nonmarine sandstones were deposited in distributary channels, in river channels, and on the broad floodplains of the rivers. Some sand bodies, 100 or more feet thick, cut through many of the underlying rock units. The shales were deposited mainly on floodplains. Fresh-water limestones and some shales were deposited locally in fresh-water lakes and swamps. The coals were formed by the accumulation of plant material, usually where it grew, beneath the quiet waters of extensive swamps which prevailed for long intervals on the emergent delta lowland. Lush forest vegetation, which thrived in the warm, moist Pennsylvanian climate, covered the region. The origin of the underclays beneath the coals is not exactly known, but they were probably deposited in the swamps as slackwater muds before and during the formation of the coals. The formation of coal marked the end of the nonmarine portion of the depositional cycle. Resubmergence of the borderland by the sea interrupted nonmarine deposition, and marine sediments were then laid down over the coal.

At the end of the Pennsylvanian Period the sea withdrew from the Illinois Basin for the last time. The Millstadt-Dupo area has remained a land area ever since.

Pennsylvanian Cyclothems

Because of the extremely variable environmental conditions under which they formed, the Pennsylvanian strata exhibit extraordinary variations in thickness and composition, both laterally and vertically. Individual sedimentary units, usually very thin and often only a few inches thick, rarely exceed 30 feet in thickness. Sandstones, shales, limestones, and coals grade laterally into one another. However, a few of the coals and several of the limestones can be traced in the subsurface over large areas of the Midwest.

The rapid and frequent changes in depositional environments during Pennsylvanian time produced regular or cyclical alternations of sandstone, shale, limestone, and coal in response to the shifting front of the Pennsylvanian delta. Each alternation or cycle, called a cyclothem, consists of several marine and nonmarine rock units which record a complete cycle of marine invasion and retreat. Based on extensive studies of the Pennsylvanian strata in the Midwest, geologists have determined that an ideally complete cyclothem consists of ten sedimentary units. The chart on the next page shows the arrangement. Approximately 50 cyclothems have been described



10 Shale, gray, sandy at top; contains marine fossils and ironstone concretions, especially in lower part.

9 Limestone; contains marine fossils.

8 Shale, black, hard, laminated; contains large spheroidal concretions and marine fossils.

7 Limestone; contains marine fossils.

6 Shale, gray; pyritic nodules and ironstone concretions common at base; plant fossils locally common at base; marine fossils rare.

5 Coal; locally contains clay or shale partings.

4 Underclay, mostly medium to light gray except dark gray at top; upper part noncalcareous, lower part calcareous.

3 Limestone, argillaceous; occurs in nodules or discontinuous beds; usually nonfossiliferous.

2 Shale, gray, sandy.

1 Sandstone, fine-grained, micaceous, and siltstone, argillaceous; variable from massive to thin-bedded; usually with an uneven lower surface.

AN IDEALLY COMPLETE CYCLOTHEM

(Reprinted from Fig. 42, Bulletin No. 66, Geology and Mineral Resources of the Marseilles, Ottawa, and Streator Quadrangles, by H. B. Willman and J. Norman Payne)

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in the Illinois Basin, but only a few contain all ten units. Usually one or more are missing because conditions of deposition were more variable than indicated by the ideal cyclothem. However, the order of units in every cyclothem is almost always the same. A typical cyclothem includes a basal sandstone overlain by an underclay, coal, black sheety shale, marine limestone, and gray marine shale. In general the sandstone-underclay-coal portion (the lower 5 units) of each cyclothem is nonmarine and was deposited on the coastal lowlands from which the sea had withdrawn. However, some of the sandstones are entirely or partially marine. The units above the coal are marine sediments and were deposited when the sea advanced over the delta lowland.

Origin of Coal

It is generally accepted that the Pennsylvanian coals originated by the accumulation of vegetable matter, usually in place, beneath the waters of extensive, shallow, fresh to brackish swamps. They represent the last-formed deposits of the nonmarine portions of the cyclothems. The swamps occupied vast areas of the deltaic coastal lowland, which bordered the shallow Pennsylvanian sea. A luxuriant growth of forest plants, many quite different from the plants of today, flourished in the warm Pennsylvanian climate. Today's common deciduous trees were not present, and the flowering plants had not yet evolved. Instead the jungle-like forests were dominated by giant ancestors of presently-existing club-mosses, horsetails, ferns, conifers, and cycads. The undergrowth also was well developed, consisting of many ferns, fernlike plants, and small club-mosses. Most of the plant fossils found in the coals and associated sedimentary rocks show no annual growth rings, suggesting rapid growth rates and lack of seasonal climatic variations. Many of the Pennsylvanian plants, such as the seed ferns, became extinct.

Plant debris from the rapidly growing swamp forests, composed of leaves, twigs, branches, and logs, accumulated as thick mats of peat on the floors of the swamps. Normally, vegetable matter rapidly decays by oxidation to water, nitrogen, and carbon dioxide. However, the cover of swamp waters, which were probably stagnant and low in oxygen, prevented the complete oxidation and decay of the peat deposits.

The periodic invasions of the Pennsylvanian sea across the coastal swamps killed the Pennsylvanian forests and initiated marine conditions of deposition. The peat deposits were buried by marine sediments. Following burial, the peat deposits became gradually transformed into coal by slow chemical and physical changes in which pressure (compaction by the enormous weight of overlying sedimentary layers), heat (also due to deep burial), and time were the most important factors. Water and volatile substances (nitrogen, hydrogen, and oxygen) were slowly driven off during the coalification process, and the peat deposits were changed into coal.

Coals have been classified by ranks which depend on the degree of coalification. The commonly recognized ranks of coal, in order of increasing rank, are (1) brown coal or lignite, (2) sub-bituminous, (3) bituminous, (4) semibituminous, (5) semianthracite, and (6) anthracite. Each higher rank is characterized by increasing amounts of fixed carbon and decreasing amounts of oxygen and other volatiles. Hardness of coal also increases with increasing rank. All of Illinois' coals are bituminous.

Underclays occur beneath most of the coals in Illinois. Because underclays are generally unstratified (unlayered), are leached and possess a bleached appearance, and generally contain plant roots, many geologists consider them to represent the ancient soils on which the coal-forming plants grew.

The exact origin of the carbonaceous black shales, which occur above many coals, is uncertain. The black shales probably are deposits which formed under restricted marine (lagoonal) conditions during the initial part of the invasion cycle, when the region was partially closed off from the open sea. In any case they were deposited in quiet water areas where very fine, iron-rich muds and finely-divided plant debris were washed in from the land. The high organic content of the black shales is also in part due to the carbonaceous remains of plants and animals that lived in the lagoons. The fossil remains of animals in the black shales are sometimes depauperate (dwarf) because they were stunted by toxic conditions in the sulfide-rich waters of the lagoons. The phosphatic siderite nodules, which occur in the black shales, were formed by chemical precipitation of calcium carbonate, iron carbonate (siderite), and phosphate from the brackish lagoonal waters. These features suggest slow rates of shale deposition.

ITINERARY

0.0 0.0 Assemble on West Mill Street in front of Millstadt Grade School.

Proceed east. Cross North Monroe and North Main Streets.

STOP. North Jefferson Avenue.

0.15 0.15 Turn left (north) on North Jefferson Avenue (Route 163).

0.25 0.4 Leave Millstadt. Continue ahead north.

1.25 1.65 SLOW. Entrance to Peabody Coal Company, Midwest Mine on right.

Continue ahead.

0.85 2.5 Cross narrow bridge over Prairie Du Pont Creek.

SLOW. Prepare to turn right.

0.2 2.7 Crossroad--turn right (east) on Concordia Church Road.

0.4 3.1 Cross Prairie Du Pont Creek.

1.0 4.1 Stop 1. Pleistocene drift exposed in roadcut on right (NE 1/4 NW 1/4 NW 1/4, sec. 35 and SE 1/4 SW 1/4 SW 1/4, sec. 26, T. 1 N., R. 9 W.).

Both the Kansan (about 700,000 years ago) and the Illinoian (about 250,000 years ago) glaciers advanced into the Millstadt-Dupo area from the northeast. Drift of Kansan age has not been definitely recognized in this vicinity, although patches of deeply weathered till above the bedrock in the strip mine area northeast of Millstadt may be Kansan. It appears that the Kansan glacial deposits were completely stripped away during the long interval of erosion that took place during the post-Kansan Yarmouthian interval (see attached Pleistocene Time Table).

The Illinoian glacier completely covered the field trip area, advancing just beyond the bluffs of the Mississippi Valley. The glacier is believed to have crossed the American Bottoms at East St. Louis. Till, an ice-laid deposit, and outwash of Illinoian age occur extensively on the bedrock surface in this region and are exposed at many places. In a few places Illinoian loess, deposited ahead of the advancing Illinoian glacier, is preserved beneath the till. Illinoian till overlain by younger Wisconsinan loess deposits is exposed in this roadcut. This roadcut and those at the next two stops afford excellent opportunities to examine these glacial deposits which form the surficial materials throughout the field trip area. The section exposed here is as follows:

	Thickness (feet)
WISCONSINAN	
Woodfordian	
Peoria Loess - silt, tan-brown, clayey, massive leached; deep reddish tan in upper 6 feet (modern soil)	10-12
Altonian	
Roxana Silt - silt, brown with pinkish cast, clayey, massive, leached; gray-mottled with small quartz and chert pebbles in lower few inches to one foot (colluvium) .	6-8
ILLINOIAN	
Till - mottled reddish tan to orange-gray, deeply weathered, leached, Sangamon Soil in upper 6 feet; silty, clayey; numerous quartz pebbles and angular chert fragments; scattered small igneous rock fragments (base not exposed)	8-10

The Illinoian till is well exposed at the west end of the roadcut, north of the road. The upper 6 feet of the till is limonite- and manganese-stained. This deeply weathered zone is the Sangamon Soil, an ancient buried soil that was formed during the warm interglacial interval that followed the Illinoian glaciation. This interval of weathering, called the Sangamonian, lasted from about 200,000 to 70,000 years ago. The Sangamon Soil in this immediate locality was apparently developed under poorly drained conditions and lacks the distinctive reddish color of well-drained profiles.

The Sangamon Soil is extensively developed on the Illinoian glacial deposits throughout the Midwest. The soil is an important stratigraphic marker in areas of thick drift where more than one till layer is present. Where till units above and below are not completely leached, the soil zone can be detected by testing with dilute acid (HCl). Unleached till bubbles when acid is applied due to a reaction with carbonate minerals (calcite and dolomite). Carbon dioxide gas is given off. The till exposed here is only very slightly calcareous below the soil zone.

Till is an ice-laid material, deposited while the glacier was still moving. It was deposited by a kind of plastering action as rock debris was released by melting at the base of the glacier. Till is characterized by its massive, unstratified structure and by its unsorted texture, consisting of a random mixture of clay, silt, sand, gravel, and larger-sized rock debris. Boulders are common because ice has virtually unlimited transporting competence. Tills consist of rock debris eroded from the areas over which the glaciers moved. In addition to locally derived rock debris, the tills in Illinois contain a large variety of igneous and metamorphic rocks that were eroded from areas in Canada and carried hundreds of miles by the glaciers. The Illinoian till exposed here and throughout the Millstadt-Dupo area is notably lacking in coarse rock debris. The Paleozoic rocks over which the glacier moved while crossing Illinois consist predominantly of Pennsylvanian shales and sandstones. These were easily crushed and pulverized during transport by the ice. The igneous rock fragments, which are very hard, are also small, probably because the distance from their source is so great that even they were reduced in size by abrasion. The absence of coarse fragments is also due in part to the highly weathered condition of the till.

The Wisconsinan glacier did not reach the Millstadt-Dupo area. At its greatest extent during the Woodfordian advance, the glacier lay 75 miles to the northeast in Shelby County. However, during the Wisconsinan glaciation loess was deposited far beyond the areas covered by the ice. The Roxana Silt and the Peoria Loess are loess deposits that record events of the Wisconsinan glaciation in this area. The loess deposits, consisting principally of very fine, powdery silt, were laid down by the wind. The silt was eroded from outwash in the Mississippi Valley.

There were two major advances of the Wisconsinan glacier into the Midwest. These advances, called the Altonian and the Woodfordian, both entered Illinois from the northeast (fig. 5). The Roxana Silt, the lower loess in this exposure, was deposited during the advance and retreat of the Altonian glacier between 70,000 and 28,000 years ago. During the Altonian glaciation meltwater from the ice front in Minnesota and Wisconsin was depositing a thick valley train in the Mississippi Valley. Wherever it occurs, the Roxana has a characteristic pinkish brown color. The Roxana is usually less than 10 feet thick in the field trip area.

The Peoria Loess was deposited mainly during the advance and retreat of the Woodfordian glacier between 22,000 and 12,000 years ago. During the Woodfordian glaciation great amounts of meltwater again flowed down the Mississippi Valley and deposited another thick valley train of outwash. Loess deposition also continued during a later glaciation, the Valderan, from about 10,000 to 6,000 years ago. The Valderan glacier did not enter Illinois.

The Peoria Loess is typically tan in color. It is as much as 50 feet thick on the Mississippi bluffs in the field trip area. The contact between the Peoria Loess and the Roxana Silt is difficult to see. By standing back from the exposure the color differences are quite evident.

Leave Stop 1. Continue ahead.

0.1 4.2 Driveway from right. Turn around and return toward west.

0.45 4.65 Stop 2. Pleistocene drift exposed in roadcut on left (SE 1/4 SE 1/4 SE 1/4, sec. 27, T. 1 N., R. 9 W.).

The exposure here is as follows:

	Thickness (feet)
WISCONSINAN	
Woodfordian	
Peoria Loess - silt, tan-brown, clayey, massive, leached	10
Altonian	
Roxana Silt - silt, brown with pinkish cast, clayey, massive; pinkish to reddish, pebbly colluvium in lower foot or so	8
ILLINOIAN	
Till - mottled gray and yellow-tan, deeply weathered, leached; 0 - 2 feet of sandy gravel at top; conspicuous reddish Sangamon Soil in upper 5 feet (base not exposed)	7

In this exposure the Sangamon profile is developed partially on Illinoian outwash. The profile is well-drained and displays the vivid reddish brown color that is typical of the soil in many parts of Illinois. It is conspicuously noticeable on the surface of the outcrop.

The colluvial zone at the base of the Roxana is thicker than at Stop 1. This colluvial material represents a mixture of loess and slopewash debris that was eroded from the underlying Illinoian till and mixed with the loess during the initial phase of loess deposition. Reddish material eroded from the Sangamon profile is present in the colluvium.

Leave Stop 2. Continue ahead west.

0.15 4.8 On the left are old strip mine spoil banks from the mining of the No. 6 Coal.

The spoil piles here belong to the Peabody Coal Company's Midwest Mine. The Herrin (No. 6) Coal was mined. The coal averaged about six feet in thickness and occurred under less than 50 feet of overburden in this immediate vicinity. The Midwest Mine has been in operation since 1940, and at the present time the company has a strip pit and a "hi-wall" mine east of Freeburg.

St. Clair County produced over 7 million tons of coal from four mines during 1968, which ranked it third out of 24 Illinois counties producing coal that year. The value of this coal at the mines amounted to slightly less than $28.5 million. The county has reported coal production for 87 years (1882-1968) with a total of over 296 million tons. This ranks the county third highest in all-time production among the 71 coal-producing counties of Illinois. The majority of the coal produced to date has been from the No. 6 Coal, with minor amounts locally from other thinner coals.

Pennsylvanian sedimentary rocks form the bedrock surface over approximately four-fifths of Illinois and have a maximum cumulative thickness of about 3,000 feet. They were deposited between 270 and 310 million years ago and contain all of Illinois' minable coal beds, whose recoverable reserves are estimated at 137 billion tons. Coal is one of the state's most important mineral resources, accounting for over one-third of the total mineral production value, which in 1968 amounted to approximately $670.7 million. In 1968, over 62 million tons of coal valued at over $249 million were mined in Illinois, ranking the state fourth among the coal-producing states in the nation.

0.4 5.2 SLOW. Descend into valley of Prairie Du Pont Creek.

The roadcut on the right exposes Peoria Loess (7'), Roxana Silt (7'), Illinoian till (0-2') overlying Pennsylvanian shale. Erosion along Prairie Du Pont Creek during post-Illinoian time removed most of the Illinoian till. The contact between the till and the bedrock is well exposed. The till is greenish because of the shale that was incorporated into it as the glacier moved over the bedrock surface. The Sangamon Soil extends through the till and into the upper few feet of the shale.

0.15 5.35 Cross Prairie Du Pont Creek. STOP.

Stop 3. Exposure of Pennsylvanian strata in banks of Prairie Du Pont Creek (N 1/2 NW 1/4 NW 1/4, sec. 34 and SE 1/4 SW 1/4 SW 1/4, sec. 27, T. 1 N., R. 9 W.).

North and south of the bridge along Prairie Du Pont Creek a thick section of lower Pennsylvanian rocks is exposed (fig. 7). The upper part of the section is

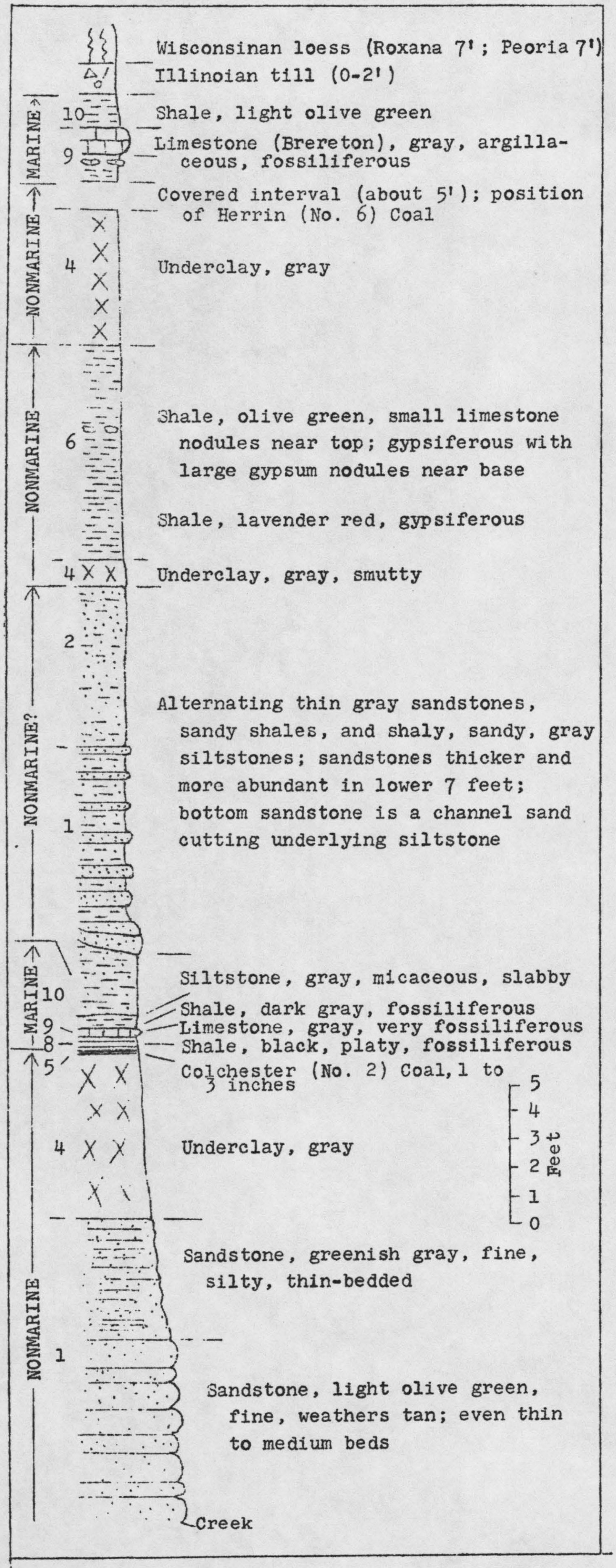


Fig. 7 - Strata exposed at Stop 3.

poorly exposed in the ditch and roadcut east of the bridge. These strata exhibit beautifully the extremely variable and cyclical character of Pennsylvanian sedimentary rocks. Portions of two formations and three cyclothems are exposed. The sandstone (best exposed north of the bridge) and the lowermost underclay belong to the Spoon Formation. The Colchester (No. 2) Coal and all of the overlying strata belong to the Carbondale Formation.

The thinness of rock units clearly illustrates the diversity of sedimentary conditions that existed in this area during their deposition. In figure 7 an attempt has been made to designate the probable marine and nonmarine portions of the section. However, this is only a gross estimation because only strata containing marine fossils can be safely designated marine. Although indicated as nonmarine, some of the sandstone, siltstone, and shale units, or portions of them, may have been deposited under nearshore marine conditions. Evenly bedded, slabby sandstones and siltstones, like those above the No. 2 Coal in this exposure, are characteristic of sediments deposited on floodplains along river channels and in shallow nearshore areas. The thin channel sandstone above the No. 2 Coal may have been deposited in a shallow tidal channel just offshore. Some of the sandstone beds are finely ripple-marked, attesting to the shallow water in which they were laid down.

As is typical, the cyclothems exposed here do not contain all 10 units of the ideal cyclothem. Some units were never deposited because the changes from marine to nonmarine environments, and vice-versa, were extremely abrupt and frequent. During periods of emergence strata were removed by erosion. Sedimentary conditions in the Millstadt-Dupo area during the Pennsylvanian Period were more variable at times than in areas in the deeper parts of the Illinois Basin. In addition, emergent conditions and erosion or nondeposition seem to have been prevalent much of the time because of the effect of the Ozark Dome just to the west. The Dupo Anticline also seems to have affected sedimentation locally. The Pennsylvanian strata thin toward the axis of the anticline suggesting that movements of the structure were taking place during early Pennsylvanian time. More evidence of this will be seen later at Stop 13. The area over the anticline seems to have been topographically higher than adjacent areas and to have received less sediment. In this immediate vicinity the stratigraphic interval from the No. 2 Coal to the underlying Mississippian rocks is only about 25 feet. Just three miles to the northeast near Belleville, this interval is more than 100 feet. The interval between the No. 2 Coal and the No. 6 Coal also increases in this distance from about 30 feet to 80 feet. In the deepest part of the Illinois Basin the interval from the No. 2 Coal to the base of the Pennsylvanian is as much as 1,200 feet. This much greater thickness of strata accumulated there in the same amount of time because of the greater amount of subsidence.

The No. 2 Coal is one of the most widespread and economically important coals in Illinois. It is extensively mined in western and eastern Illinois where it reaches thicknesses of several feet. In the field trip area the No. 2 Coal is very thin, although just a mile to the northeast of this locality it is about 22 inches thick and has been locally mined. Swampy conditions did not prevail long enough to permit a thick coal to develop here. The No. 6 Coal, called the Herrin Coal, is the economically important coal in the field trip area, and it has been mined in many places, including just to the southeast (see Itinerary Map). It is not exposed in this section but is probably present in the covered interval below the roadcut. A thin underclay in the middle of the section has no associated coal. Swampy conditions existed for a short time but either no coal formed or it was eroded away. Red shale immediately above the underclay suggests that the sediments above the underclay were deposited under emergent conditions and subjected to a highly oxidizing environment. Oxidizing conditions would have prevented the accumulation of peat.

The designation of the coals in Illinois by number began in the middle 1800's when geologists recognized that the coals were widespread and easily identified. They numbered the coals in an attempt to better understand and interpret the Pennsylvanian strata. The coals were numbered consecutively from the oldest (lowest) to youngest (highest) in the section. Later the geologists discovered additional coal beds that had not been previously recognized, thus adding confusion to the numbering system. Letter-number combinations were used for a while, but it was finally decided to use geographic names in accordance with the standard practice of stratigraphic nomenclature. However, because of long usage, the numbers, along with geographic names, are still used for the more widespread, commercially important coals.

Leave Stop 3. Continue ahead west.

0.35	5.7	STOP. Route 163. CAUTION. Dangerous intersection.
		Turn right (north).
0.55	6.25	T-road from left. Turn left (west) on Forest Hill Road.
0.25	6.5	Note the undulating nature of the upland surface in this vicinity. Also note the general evenness of the horizon to the west and southwest. These will be discussed later.
1.1	7.6	Turn right (north). Stay on blacktop.
0.5	8.1	Y-intersection. Turn left on blacktop.
0.6	8.7	Descend into valley of Hickman Creek. Note the flatness of the valley bottom.

0.4 9.1 Cross Hickman Creek.

0.2 9.3 T-road intersection. Turn right (north).

0.3 9.6 STOP. T-road intersection. Turn left (west).

0.9 10.5 Entering the eastern edge of an extensive area of sinkhole topography. Note the sinkhole on the left.

0.45 10.95 4-way STOP. Turn right (north) on blacktop.

0.95 11.9 Water-filled sinkhole on the left.

0.4 12.3 Descend into Mississippi Valley. The flat expanse of the American Bottoms stretches to the north. This portion of the valley is a vast, alluviated lowland 25 miles long and 11 miles wide at its maximum, extending from the vicinity of Alton southward to Dupo. This lowland was cut by the Ancient Mississippi River into the relatively easily eroded, shaly Pennsylvanian strata. This erosion was accomplished by glacial floodwaters during the Ice Age, mainly during the Nebraskan and Kansan glaciations. The valley narrows abruptly to about 3 1/2 miles at Dupo where the relatively more resistant Valmeyeran (middle Mississippian) limestones are brought to the surface on the Dupo Anticline. The bedrock floor of the valley in the field trip area lies as much as 170 feet below the level of the present floodplain. The alluvium that fills the valley consists principally of sand and gravel that was deposited by meltwaters from the Wisconsinan glacier.

1.0 13.3 Y-intersection. Bear left.

0.15 13.45 STOP. Continue ahead. Bear left.

0.3 13.75 Casper-Stolle Quarry on left. The St. Louis and Ste. Genevieve Limestones are being quarried.

0.15 13.9 T-road from left. Turn left and enter property of East St. Louis Stone Company, Falling Springs Plant.

CAUTION. WATCH FOR TRUCKS.

0.5 14.4 Entering loading and preparation plant area. Quarry on left in St. Louis and Ste. Genevieve Limestones.

Continue south past scale house.

The thick Mississippian limestones in the Mississippi Valley are the basis of an important quarrying industry. Limestone is also one of Illinois' most important mineral commodities. In 1967, approximately 44.8 million tons of crushed limestone and dolomite valued at $63.1 million were produced by Illinois quarry operators. Principal uses for this stone were as concrete aggregate, roadstone, and agricultural lime.

0.3 14.7 Note the steep limestone bluff on the left.

0.15 14.85 West gate of quarry area. Continue ahead.

0.1 14.95 T-road from right. Continue ahead.

Note the small caves in the bluff on the left.

0.3 15.25 T-road intersection. Turn left and enter Falling Springs Conservation Area.

0.05 15.3 STOP. Continue ahead through parking lot.

0.1 15.4 Stop 4. Falling Spring (SE 1/4 SE 1/4 SE 1/4, sec. 15, T. 1 N., R. 10 W.).

At this locality the valley bluff rises almost vertically to a height of over 200 feet, exposing approximately 100 feet of the St. Louis Limestone overlain by 20 feet of the Ste. Genevieve Limestone. The St. Louis Limestone consists predominantly of gray, fine-grained, medium- to thin-bedded limestone. Two zones of light tan, somewhat massive dolomite occur in the middle part of the exposure. The upper dolomite is a conspicuous unit that varies in thickness and exhibits an extremely undulating upper surface. This irregular surface, which has a maximum relief of about 10 feet, is believed to be a submarine erosion surface or unconformity. Limestone deposition apparently was interrupted here for a while and the upper surface of the limestone was scoured by tidal currents. When limestone deposition resumed, the thin-bedded gray strata that overlie the dolomite filled the depressions and buried the erosion surface.

An unconformity is also present between the St. Louis Limestone and the Ste. Genevieve Limestone, but it has little relief in this exposure and is not obvious. After the St. Louis Limestone was deposited, the sea withdrew temporarily and a period of erosion followed. The Ste. Genevieve consists predominantly of light gray oolitic limestone. The limestone is strongly cross-bedded, indicating deposition under shallow, turbulent conditions. Strongly inclined, large-scale cross-bedding is quite conspicuous in the limestone at the top of the bluff.

The feature of special interest at this locality is Falling Spring, a famous local curiosity. The spring emerges from a small cavern in the evenly bedded strata of the St. Louis Limestone, several feet below the massive dolomite bed. A few hundred yards to the northeast, several other caverns occur in the St. Louis. The latter are concentrated in the massive dolomite bed.

The spring is an outlet for subterranean drainage from the sinkhole area on the upland to the east. Flow, although quite small, is steady, suggesting that several sinkholes may be draining into this system. A similar opening 50 feet to the north has no spring. During periods of extremely wet weather, flow has also been noted from a few of the openings to the north. The water emerging from the spring is highly charged with dissolved calcium carbonate. A small mound of calcareous tufa is accumulating at the base of the spring. As the water splashes on the ledge, the loss of carbon dioxide and slight warming of the water causes the precipitation of calcium carbonate.

The openings in the cliff face in this locality form part of a network of subterranean caverns and passages that permeate the Valmeyeran limestones in this region. This network is concentrated in the thick St. Louis Limestone, indicating that some characteristic of this formation makes it especially susceptible to the development of solutional features. The subterranean solution features of this region are believed to predate the cutting of the Mississippi Valley. The small passages at this locality have been truncated (cut off) by cutting of the valley bluff and must have continued for some distance to the west.

Two opposing theories have been offered by geologists to explain the formation of caves. One theory is that caves form mainly above the water table by the scouring (abrasive) and solutional activity of underground streams or "vadose" water. By this theory, acid-charged meteoric water (rainwater) from the soil percolates downward along cracks and joints in the limestone, becomes concentrated into flowing streams, and gradually enlarges the openings to produce a network of subterranean caverns. Such a theory proposes that there be ample rainfall, near-surface, highly fractured limestone formations, and adequate relief, such as adjacent to a deep valley, to permit groundwater flow.

A second theory, more widely accepted by geologists, proposes that limestone caverns form mainly below the water table in the "phreatic" zone where groundwater moves slowly under hydrostatic head. A deeply entrenched valley is not needed to provide an outlet for groundwater. The groundwater moves slowly down a regional gradient. Recharge from the surface continually supplies fresh water which slowly dissolves the limestone and carries the calcium carbonate away in solution. Joint patterns and bedding in the limestone strongly affect the configuration of the cavity system that forms. The caves in the Mississippi Valley region are mainly of phreatic origin. They formed late in the Tertiary Period, probably during the latter part of the Pliocene Epoch, which lasted from 10 million to 1 million years ago. At that time the region was a vast, gently undulating erosional plain sloping to the south. The present Mississippi Valley did not exist.

Leave Stop 4. Leave conservation area and proceed northwest toward Prairie Du Pont.

1.15 16.55 STOP. T-intersection with Routes 50 and 3. Turn left. CAUTION.

0.15 16.7 Railroad crossing. Enter city of Dupo.

0.1 16.8 On the left in the distance, note the steep bluff of the Mississippi Valley. The Mississippian strata in the bluff slope gently upward to the southwest toward the axis of the Dupo Anticline.

0.7 17.5 Columbia Quarry in the bluff line on the left. Columbia Quarry is one of the largest stone quarries in Illinois. About 140 feet of the St. Louis Limestone is being quarried.

1.9 19.4 Entrance to Columbia Quarry Company, Dupo Plant No. 9 on left.

Turn left on quarry road. Park on right shoulder.

Stop 5. Discussion of Dupo Anticline (NW 1/4 NW 1/4 SE 1/4, sec. 28, T. 1 N., R. 10 W.).

The Dupo area affords a remarkable opportunity, perhaps the best in Illinois, to examine a major bedrock structure. In the face of the bluff to the southeast an almost complete cross section of the Dupo Anticline is exposed to view. The crest of the anticline passes through the slight saddle in the bluff line to the northeast of Sugarloaf Heights (see Itinerary Map). Along the crest of the anticline the strata have been arched several hundred feet, bringing formations as old as the Burlington Limestone to the surface near Columbia. The Ullin Limestone, the Salem Limestone, and the St. Louis Limestone are exposed in the bluffs directly ahead.

The anticline is strongly asymmetrical with the strata on the west limb dipping (tilting) more steeply than those on the east limb. Dips as great as 50 degrees have been observed on the west limb in the vicinity of Columbia. Dip angles on the east limb are very gentle, usually about 2 degrees but occasionally as much as 5 degrees. The asymmetry of the fold is quite obvious at this exposure. In the bluffs at Sugarloaf Heights the beds on the west limb are dipping at about 30 degrees.

The Dupo Anticline is a rather sharp, narrow structure that can be traced in the subsurface from south of Waterloo, past Dupo, to beyond St. Louis, a distance of more than 25 miles. There is some evidence that faulting has occurred in places along the steep west limb of the anticline. The axis of the fold (the horizontal projection of a line along its crest) has a general northwesterly trend. The Florissant Dome, an anticlinal structure north of St. Louis, is apparently a further extension of this fold to the north. The trend of the anticline is clearly evident from the outcrop pattern of the bedrock formations (fig. 2). Erosion and truncation of the structure has exposed progressively older formations along its crest. Along the crest there are two high areas on the fold separated by a saddle. The highest part of the fold occurs just north of Waterloo. A second, smaller high occurs here at Dupo. These highs are elongated domes or closures that were the sites of oil accumulation. The Waterloo and Dupo oil fields are located on these domes.

This stop is in the Dupo field, and several abandoned oil wells can be seen on the floodplain in this vicinity, as well as a pumping well on the talus about half way up the bluff. The pay zone is the top of the Kimmswick ("Trenton") Limestone of Ordovician age which occurs at a depth of approximately 400 feet below the surface of the valley bottom here (fig. 1). The Kimmswick is a coarse-grained, crystalline, moderately porous limestone that averages about 100 feet in thickness in this region. The upper portion of the limestone contains fissures and crevices that are probably due in part to pre-Maquoketa weathering and erosion. Some of the porosity may also be due to shattering of the limestone along faults during folding of the anticline. The anticline is somewhat of a classic example of a natural oil trap. The oil accumulated in the Kimmswick at the top of the structure and was prevented from escaping further upward by an impervious caprock of the overlying Maquoketa Shale.

The Dupo oil field was discovered by the Ohio Oil Company with the completion of the Tarleton No. 1 well in November, 1928. This well, which produced 150 barrels of oil naturally in the first 24 hours, is located in the SW 1/4 SE 1/4 SE 1/4 sec. 28, T. 1 N., R. 10 W. (on the ridge top and slightly to the left of the crest of the structure as viewed here from Stop 5).

The crustal movements which produced the Dupo Anticline may have begun as early as Devonian time, some 350 million years ago. Major movements occurred near the end of the Mississippian Period and at the end of the Pennsylvanian Period. Other structures in Illinois, including the Valmeyer Anticline near Valmeyer to the south and the Lincoln Anticline near Alton to the north, were also forming. These were times when crustal forces were forming mountain ranges along the eastern margin of North America.

Leave Stop 5. Turn around and turn left (south) on Route 3. CAUTION.

0.8	20.2	T-road from left. Turn left (east) on Imbs Station Road. Enter Cement Hollow.
0.3	20.5	On the right across Hill Creek note the steeply dipping beds of St. Louis Limestone. The strata are tilted about 30 degrees west on the west limb of the Dupo Anticline.
0.15	20.65	Crossing axis of Dupo Anticline. Oil wells and oil storage facilities on the left.
0.1	20.75	High on the slope to the left, note the eastward dipping beds of the Ullin Formation. These beds are on the east limb of the anticline.
0.2	20.95	Eastward dipping limestone beds on the right. The dip is very gentle, only 2 degrees.
0.05	21.0	Stop 6. Abandoned cement mine on south (right) side of Cement Hollow Road (NE 1/4 SW 1/4 NW 1/4, sec. 34, T. 1 N., R. 10 W.).

A 6- to 8-foot bed of argillaceous dolomitic limestone containing silica, alumina, iron oxide, and calcium magnesium carbonate in proper proportions was the source of stone used in making "natural" cement here about 1865. The dolomitic limestone that was mined occurs near the top of the Mississippian Ullin Limestone. The Ullin is more than 60 feet thick in the field trip area and has been exposed in this locality by the cutting of Cement Hollow across the axis of the anticline. The two-story house located on the other side of the road served as the cook's quarters when this mine and its kilns were in operation. The kilns and grinders were located west of the garage on the same property. Roof conditions in the mine are excellent, and the tunnelways are in very good condition in spite of the many years that have passed.

Cement rock is impure, usually argillaceous limestone which can be burned as it occurs, or with minor alterations, to make cement. The raw material (limestone) should contain 10-22 percent silica and 4-16 percent alumina and iron oxide. A chemical analysis of rock mined here revealed 51 percent calcium carbonate, 22 percent magnesium carbonate, 17 percent silica, 4 percent alumina, and 2 percent iron oxide. Many cement rocks carry a considerable percentage of magnesium carbonate which, for natural cement, unlike Portland cement, has no harmful effects and may be considered as practically the equivalent of a similar percent of calcium carbonate. The limestone should have a fairly constant chemical composition both vertically and laterally. The process of manufacture of natural cement consists of burning the quarry-run stone fragments to a temperature slightly above that required to liberate carbon dioxide and water. The burned limestone is cooled and then pulverized.

Leave Stop 6. Continue ahead.

0.1	21.1	Stop 7. Wooden oil storage tanks and abandoned oil well on north side of Cement Hollow Road (NE corner NE 1/4 SW 1/4 NW 1/4, sec. 34, T. 1 N., R. 10 W.).

This well, Gaskill No. 4, is located less than one-quarter mile east of the crest of the Dupo Anticline and just slightly to the south of the highest closure of the Dupo oil field. The hole bottomed in the Trenton pay zone at depths from 634 to

672 feet. The surface elevation at this well site is approximately 625 feet above sea level. Initial production from this well was 70 barrels per day by pumping. The Dupo Oil Company moved a work-over rig into position to service the well some time ago, but because of equipment failure, they have been unable to restore the well to production.

During the early days of oil production in this field, wells capable of producing oil were sometimes "shut-in," or not allowed to produce because of the lack of oil storage facilities. Wooden storage tanks such as these were constructed on the hillsides for storage where it apparently was too difficult to place steel tanks. Not only were storage facilities needed for oil, but also for the large volumes of salt water produced along with the oil. Salt water disposal has been one of the biggest problems associated with this field. For example, one well in this field equipped with a centrifugal pump, rather than with a pumpjack as used here, produced approximately 47,000 barrels of oil and 903,000 barrels of salt water during an eight months' operating period. Some wells have been drilled for use as salt water disposal wells in order to return these large volumes of water to the subsurface.

The Dupo oil field has a proven productive area of 2,400 acres. It has had as many as 292 productive wells. Only a few are now producing oil. Total oil production from this field has been estimated at 2,883,000 barrels. Oil produced early in the life of the field was refined for gasoline by two local refineries which were abandoned in later years. Since no oil from the Dupo entered the local pipeline during 1968, no production was reported officially from this field even though an unknown quantity of oil was used for road-building purposes in this region. A small amount of oil production has been reported for 1969. Apparently some of this latest production has been used for refining of fuel oil.

Illinois has had a productive oil industry for many years. At the present time crude oil is the second most valuable mineral commodity produced in the state, with an estimated production of 56.4 million barrels in 1968 valued at $173.1 million.

Leave Stop 7. Continue uphill (east).

0.1	21.2	Y-intersection. Bear right.
		Hill Creek emerges as a spring at its headwaters on the right. It drains the sinkhole area on the upland just to the east.
0.4	21.6	Entering area of numerous sinkholes.
0.9	22.5	Driveway. Bear left.
0.2	22.7	<u>Stop 8</u>. Discussion of sinkhole topography (SE 1/4 SW 1/4 NE 1/4, sec. 35, T. 1 N., R. 10 W.).

The uplands in the field trip area, where the thick Valmeyeran limestones form the bedrock surface, are pocked with numerous irregular to circular depressions called sinkholes. Solution of the limestone and the formation of the sinkholes has produced the highly undulating hummocky topography. Several sinkholes are visible from this vantage point. These sinkholes form part of a 2- to 3-mile wide tract of sinkholes that extends from the Mississippi bluff at Stolle southward for about 11 miles along the east side of the Dupo Anticline (see Itinerary Map).

The sinkhole tract follows the outcrop belt of the Valmeyeran limestones. They are especially concentrated within the area underlain by the St. Louis Limestone.

As the limestones dip eastward beneath the protective cover of the shaly Chesterian (Upper Mississippian) and Pennsylvanian formations, the sinkholes abruptly disappear. The boundary of these formations can almost be mapped by noting the areas devoid of sinkholes. Note that surface streams are almost totally absent within the sinkhole area. Surface water quickly drains down through the sinkholes into the highly fissured, underlying limestones. Some of this water emerges as springs along the bluff to the west.

Terrain characterized by subsurface drainage, caves, sinkholes, and related solutional features is called karst topography. Although sinkholes are abundant in this area, other solutional features are not developed to an extent that would justify calling the topography "karst." More appropriately it should be called "sinkhole topography." True karst areas such as those in southeastern Missouri, north central Kentucky, and southern Indiana do not exist in Illinois.

Sinkholes form in two ways--by roof collapse of caves near the surface and by solutional enlargement of fissures from the surface downward. In the former case, sinkhole formation takes place during a second stage of karst development following uplift and entrenchment of major drainage, after an initial period of cavern formation by vadose water. Collapse sinks, known as ponors, are usually deep and steep-walled. In the latter case, large subterranean cavities may not even exist. These sinkholes, called dolines, may form at any time in the karst cycle. Dolines are usually shallow, saucer-shaped depressions whose depth is controlled by the depth of the water table at the time of formation. Both types of sinks are usually present in a sinkhole area. Some of the larger sinkholes in this vicinity are probably collapse sinks, but most are dolines.

Cavern formation in Illinois occurred mainly under vadose conditions late in the Pliocene Epoch, more than 1 million years ago, and early in the Pleistocene Epoch before entrenchment of the Mississippi Valley. The establishment and entrenchment of the valley will be discussed later at Stop 9. During this time dolines were forming by phreatic solution under high water table conditions. Since entrenchment of the Mississippi Valley, the caves and sinkholes have been slowly enlarged by phreatic water. Some collapse sinks have formed. The deposition of glacial drift over the upland in the field trip area has slowed the process, but phreatic solution has continued throughout Pleistocene time and up to the present. Many sinkholes are filled or buried by till and loess.

Depressions of several feet may suddenly develop anywhere in a field when the bottoms of these plugged sinkholes open up. No doubt cultivation has been the cause of some of this. As we continue through the sinkhole area, note that the depths of the sinkholes does not determine whether they are water-filled or not. Dry, deep sinkholes may be adjacent to shallow water-filled sinkholes. Thus the water level in the sinks is not influenced by the water table. Rather it is a matter of how tightly they are plugged by drift and clay.

Leave Stop 8.

0.45	23.15	STOP. T-road intersection. Turn south.
0.45	23.6	T-road from right. Continue ahead.
0.3	23.9	Crossroads at Bluffside. Turn right toward Columbia.
0.7	24.6	Deep sinkholes in this area.

0.4 25.0 In this vicinity several plugged sinkholes are beginning to open up.

1.3 26.3 Crossroads. STOP. Columbia Quarry No. 1 to the right. Continue ahead toward Columbia.

0.5 26.8 Stop 9. Scenic view. Discussion of Illinois-Missouri uplands and Mississippi Valley (SW corner NW 1/4 NW 1/4 sec. 14, T. 1 S., R. 10 W.).

This high vantage point is located close to the crest of the Dupo Anticline, and the surface elevation of 679 feet above sea level is closely controlled by the bedrock structure. The high northward-trending ridge in this vicinity is underlain by resistant cherty limestones of the Burlington and Keokuk Formations (see Itinerary Map and figure 2).

This area is situated physiographically in the Salem Plateau Section of the Ozark Plateau Province (see attached map of Physiographic Divisions of Illinois). Late in Tertiary time the Mississippi Valley region was reduced by erosion to a surface of low undulating relief that sloped gently southward. This old erosion surface, the Ozark Peneplain, is preserved in the accordant summit heights visible at the horizon on both sides of the Mississippi River. These summit levels coincide with summit levels on the Buzzard's Point plain to the southeast in the Shawnee Hills Section in extreme southeastern Illinois, the Calhoun Peneplain to the north in the Lincoln Hills Section, and the Lancaster Peneplain in the Wisconsin Driftless Section of the Upper Mississippi Valley region.

Late in Tertiary time during the Pliocene Epoch uplift of the Ozark Dome changed the direction of slope on the Ozark Peneplain. The peneplain in this region became slightly tilted to the east, northeast, and north around the uplift. Major drainage flowed northward. Early in Pleistocene time (about 1 million years ago), with the advance of the Nebraskan glacier from the northwest, northward-flowing streams were dammed by the ice and diverted eastward and southward around the margins of the Ozark Dome. The course of the Mississippi River probably originated at this time as meltwaters sought a southward escape route. Entrenchment of the valley occurred during the post-Nebraskan Aftonian interval and during the early part of the Kansan glaciation. Maximum relief in this region was developed during the early part of Kansan time when meltwaters eroded the valley to its greatest depth. Widening, filling, and re-excavating of the valley have taken place during and since Illinoian and Wisconsinan glaciations.

The upland surface here and to the east was much more rugged before Illinoian glaciation mantled and subdued it with thin deposits of drift. The thick Wisconsinan loess deposits have further subdued the bedrock topography. The water-gap or notch through which the Mississippi flows can be seen on the horizon about 13 miles to the south-southwest. The valley is incised into the gently eastward-sloping Ozark Peneplain. Summit elevations range from 800 feet west of the river down to 700 feet or slightly less east of the river.

Leave Stop 9.

0.4 27.2 City limits of Columbia. SLOW. Descend slope to erosional bench on which Columbia is located.

0.7 27.9 Railroad crossing. CAUTION. Continue ahead on East Cherry Street.

0.1 28.0 4-way STOP. Continue ahead.

0.1 28.1 STOP. Main Street. Turn right (north) on Main Street.

1.2 29.3 Turn left on West Parkview Drive. Enter parking area at Columbia Grade School.

Stop 10. Lunch.

Leave Lunch Stop.

0.15 29.45 STOP. Turn right. Return south through town on Main Street.

1.85 31.3 STOP. Intersection with Routes 3 and 158. Turn left. CAUTION. Railroad overpass.

0.2 31.5 St. Louis Limestone dipping steeply west in the ditch on the right. These beds are on the west limb of the Dupo Anticline.

Illinoian till and Wisconsinan loess exposed in borrow pit on left side of highway. The distinctive reddish Sangamon Soil is prominent in the top of the Illinoian till.

0.15 31.65 Access to Route 158, eastbound, to the right. Enter access and park on shoulder. CAUTION.

0.15 31.8 Stop 11. Long roadcut in Ullin and Salem Formations along Route 3. (SE 1/4 NE 1/4 SE 1/4 and E 1/2 SE 1/4 SE 1/4, sec. 22; SW 1/4 NW 1/4 SW 1/4 and SW 1/4 SW 1/4, sec. 23, T. 1 S., R. 10 W.).

This long roadcut, which extends for nearly half a mile on both sides of Route 3, exposes 46 feet of the Ullin Formation and 66 feet of the overlying Salem Limestone (fig. 8). It affords an unusual opportunity to examine the character of the Ullin, which because of its very argillaceous nature in this area rarely occurs in good natural exposures. The Ullin is named for exposures in southern Illinois near Ullin in Pulaski County, where it consists of fairly pure, fossiliferous limestone.

In this region the Ullin consists predominantly of gray, argillaceous, dolomitic limestones with a few thin beds of gray to bluish gray, dolomitic shales. The shales are mainly in the lower part of the formation. Many of the limestones are coarsely fragmental and consist of a hash of marine fossil fragments. The formation is extremely fossiliferous throughout, and many fossils including brachiopods, bryozoans, corals, and crinoid stems are well preserved. In the finer grained, more argillaceous units, the fossils are extremely well preserved, including abundant delicate fronds of *Archimedes* and *Fenestrellina* (see fossil plates). A thick massive unit 20 feet from the top of the formation contains so many of these fronds lying parallel to the bedding plane that the rock appears laminated. In spite of the somewhat muddy conditions during deposition of the Ullin, a rich fauna of bottom-dwelling marine animals were able to live very well. The sea was quite shallow and turbulent at times, as indicated by the abundant beds of shell breccia throughout the formation.

The Ullin in this exposure includes three thin beds of fine-grained dolomitic limestone that contain numerous small vugs. The vugs are lined with beautiful pink druses of well-formed dolomite crystals. One of these beds occurs at the top of the formation in the same interval as the cement rock described earlier at Stop 6.

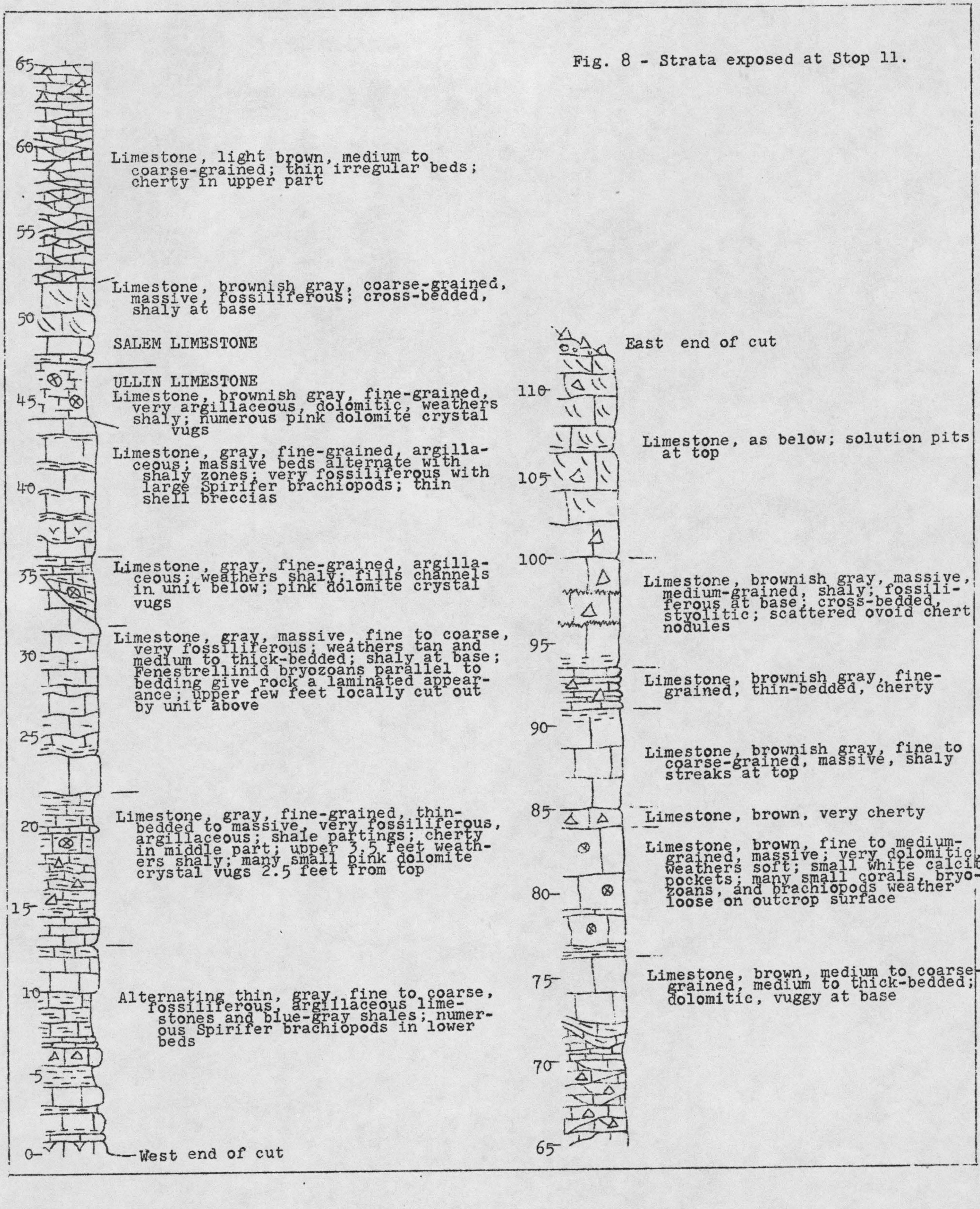


Fig. 8 - Strata exposed at Stop 11.

About 6 feet below this unit is an interval that contains great numbers of large and small Spirifer brachiopods. Spirifers are also extremely abundant in the thin-bedded limestones near the north end of the roadcut.

The Salem Limestone consists predominantly of gray-brown, relatively pure, fine to coarsely fragmental limestone. The sea did not withdraw from the midcontinent following deposition of the Ullin Limestone, so the contact between these formations is described as conformable by geologists. The depositional environment became abruptly less muddy as the amount of mud carried into this region from the north and east sharply diminished. The Salem is also very fossiliferous but most fossils are broken. Some of the limestones are cross-bedded, indicating a shallow, wave-swept environment.

Some of the limestones exposed here are cherty, a fact which renders them less desirable for quarrying purposes. The origin of the chert is not completely understood by geologists. The chert apparently was not deposited in its present form at the same time that the limestones were precipitated from the sea. Evidence for this is the fact that most of the chert is fossiliferous and thus appears to have replaced the limestone. Other sedimentary structures are also preserved in the chert. Colloidal and finely-divided silica were probably deposited in small amounts with the limestone, and some was also deposited as the siliceous hard parts of sponges, and microscopic plants and animals. Later, after solidification of the limestones, this disseminated silica was dissolved, concentrated by solution, and redeposited as the irregular bands and nodules that are now present.

		Leave Stop 11. Continue ahead on Route 158.
0.3	32.1	Bridge over Route 3.
0.4	32.5	Turn left off Route 158 onto frontage road (old Route 158).
0.55	33.05	Turn left and STOP. Turn right on Route 3 toward Columbia.
0.25	33.3	Railroad overpass.
		Turn hard left on New Hanover Road.
1.1	34.4	Valley of Carr Creek. Cross narrow bridge.
0.55	34.95	T-road from right. Continue ahead south.
0.35	35.3	Stop 12. Creek, roadcut, and quarry exposures of Mississippian Chesterian strata (S 1/2 SE 1/4 SE 1/4 sec. 28, T. 1 S., R. 10 W.).

The shales and limestones exposed in this immediate area belong to the Paint Creek Group of the Mississippian Chesterian Series (fig. 1). Green sandy, fossiliferous shale occurs above and below a 6- to 8-inch bed of greenish gray, coarsely crystalline, fossiliferous limestone in the creek bed west of the road. These beds belong to the Downeys Bluff Formation. Fossils in the limestone, in particular crinoid stem fragments, are tinted a deep reddish orange color. The shale above and below the limestone bed also contains red fossil fragments.

Overlying the light greenish gray shales and limestone is an 18-foot lavender-red, slightly green-mottled shale of the Bethel Formation. Although the shale appears rather blocky when fresh, it weathers to a fairly uniformly thin-bedded to fissile red shale. It is sandy and calcareous. The lower one foot is especially fossiliferous containing many fanlike and delicately branching Fenestrellinid bryozoan fronds. The shale extends up the slope on the east side of the road. The red color is most conspicuous.

A small abandoned quarry is located south of the red shale bank about 100 feet back from the road, just east of the farm lane. The quarry operated in a light gray to light greenish gray, very pure, coarsely clastic crinoidal, oolitic limestone of the Ridenhower Formation. The limestone is cross-bedded in the upper eight feet. The base of the limestone is not exposed in the quarry itself. Total thickness of the limestone here is at least 31 feet. What appears to be the same limestone occurs along the roadside just to the south of the lane and in the creek bottom to the west. The bottom of the limestone in the quarry is 12 feet below the top of the nearby red shale exposed in the slope just to the north. This peculiar situation indicates that a fault may be present between the quarry and the shale bank. The red shale seems to end abruptly, but cannot be seen in contact with the limestone.

A fault is a fracture in the strata along which there has been relative movement. In this case the fault block on the east side (the limestone in the quarry) has moved down relative to the block on the north side. Red shale of the Bethel normally occurs below the Ridenhower Limestone. Faulting would be expected to occur in an area of disturbed strata such as along the Dupo Anticline.

Shales in the Paint Creek Group are characteristically reddish-colored, although other Chesterian strata, including the Renault Formation, also contain red beds. These red sediments seem to occur most commonly in the region bordering the Ozark Dome. During Chesterian time the Ozark Dome was a lowland area bordering the sea on the west. Red soils were being developed on the limestones of the region. Small amounts of red clay eroded from these soils were carried eastward into the sea adjacent to the dome.

Leave Stop 12. Continue ahead south.

0.9 36.2 T-road from left. Turn left.

0.65 36.85 T-road. Turn left (east) on blacktop.

0.05 36.9 T-road from right. Continue straight ahead on blacktop.

0.3 37.2 The high ground in the distance straight ahead is along the crest of the anticline.

West of the anticlinal crest a steep erosional escarpment 100 to 150 feet high follows the trend of the anticlinal axis from Cement Hollow past Waterloo (see Itinerary Map). This escarpment and the high ground along the crest are obviously controlled by the bedrock structure. A fault probably passes along the base of the escarpment, but little direct evidence is available to confirm this.

0.2 37.4 T-road. Turn left onto gravel road.

0.3 37.7 <u>Stop 13</u>. Exposures of Pennsylvanian and Mississippian strata along Carr Creek (N/2 NW 1/4 NE 1/4 sec. 3, T. 2 S., R. 10 W. and W/2 SE 1/4 sec. 34, T. 1 S., R. 10 W.).

At this stop approximately 40 feet of the Pennsylvanian Carbondale Formation, including three coals and portions of four cyclothems, are exposed along Carr Creek and a tributary to the east(fig. 9). These rocks occur in an outlier of Pennsylvanian strata that have been preserved in the Columbia Syncline west of the Dupo Anticline. The section above the Herrin (No. 6) Coal is exposed from the trestle upstream to the south, the No. 6 Coal is well exposed just to the east of the trestle, and the section below the No. 6 Coal is exposed almost continuously for 2,500 feet to the north along Carr Creek.

The diversity of environments and the abruptness of change in depositional conditions that occurred during Pennsylvanian time are well illustrated by the strata exposed here. The marine limestones are very fossiliferous, and the shale above the Brereton Limestone contains abundant small specimens of the brachiopods Mesolobus and Chonetes. The No. 6 Coal is 30 to 36 inches thick and was mined on a small scale about 25 years ago just to the west of Carr Creek. The Summum (No. 4) Coal is also of minable thickness.

Along both Carr Creek and in the small tributary to the east the contact between the Pennsylvanian and Mississippian Systems is exposed. A remarkable exposure about 200 feet east of the trestle shows shale and underclay below the No. 4 Coal resting on steeply dipping, lower Chesterian limestone and shale (fig. 10). This locality is on the west limb of the Dupo Anticline. The Pennsylvanian beds are dipping gently westward at 9 degrees, but the Mississippian beds are dipping steeply westward at 44 degrees. The contact between these beds is an erosional surface and is called an angular unconformity. This angular relationship can also be seen to the north along Carr Creek. The much greater dip of the Mississippian strata indicates that uplift occurred on the Dupo Anticline sometime before the deposition of the No. 4 Coal. This movement occurred either late in Mississippian time or early in Pennsylvanian time. The uplift was followed by erosion and truncation of the upturned Mississippian beds underlying the No. 4 Coal. The dip of the Pennsylvanian beds above the unconformity indicates that additional movements occurred later during Pennsylvanian time.

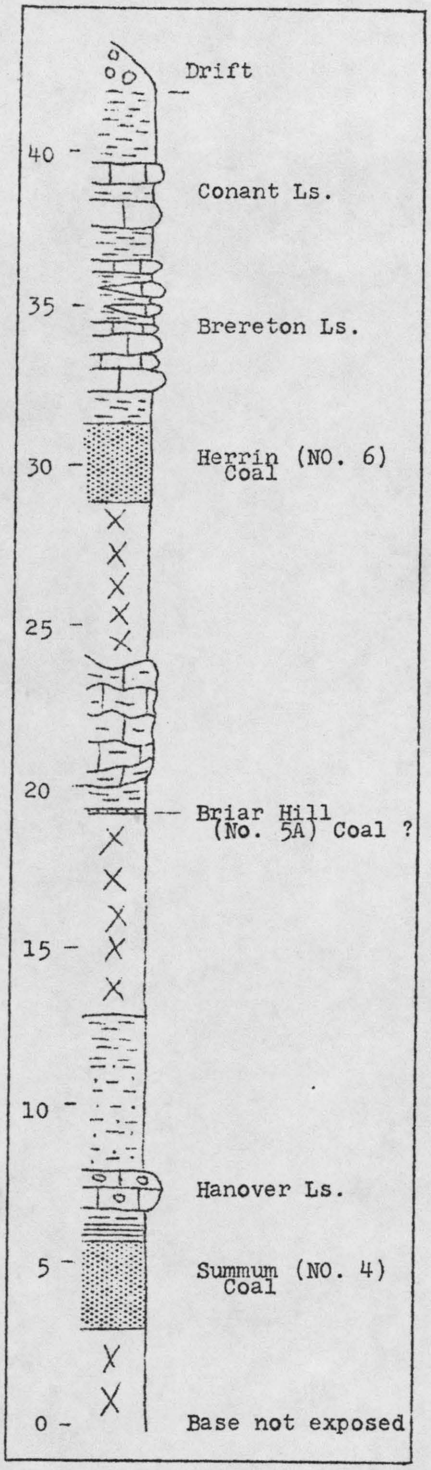


Fig. 9 - Pennsylvanian strata exposed at Stop 13.

A thick section of steeply-dipping, Chesterian formations overlying the Aux Vases Sandstone and the Ste. Genevieve Limestone is partially exposed farther to the east along the tributary valley.

Leave Stop 13. Continue ahead east beneath railroad overpass.

0.2 37.9 Stop 14. Mississippi River Transmission Corporation underground gas storage pumping station (SW 1/4 SE 1/4 SE 1/4 sec. 34, T. 1 S., R. 10 W.).

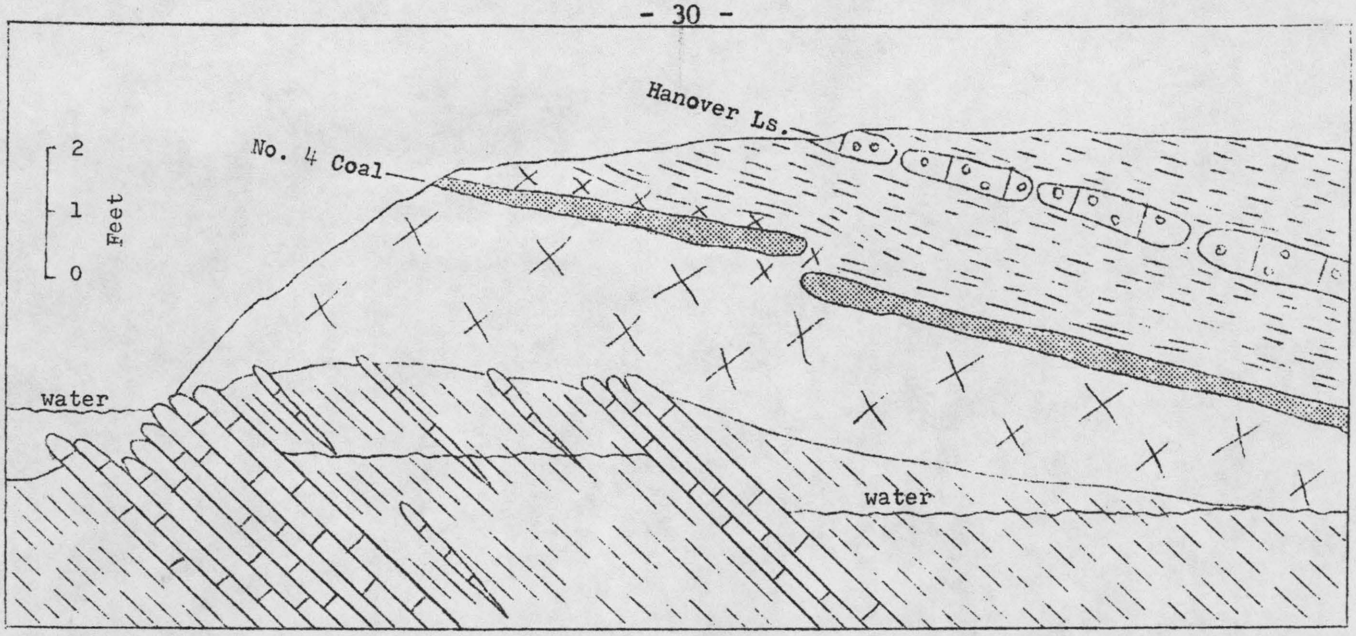


Fig.10 - Angular unconformity between Chesterian and Pennsylvanian strata as exposed in creek bank east of railroad overpass at Stop 13.

The pumping station located here belongs to the Mississippi River Transmission Corporation. Natural gas is pumped from their main pipeline about one mile to the west and distributed to a number of injection-withdrawal wells located on the Dupo Anticline to the east and southeast. Although experiments with gas storage in Illinois were made at New Harmony by Superior Oil Company in 1941, the first practical attempt was made by the Mississippi River Transmission Corporation here in the Waterloo field in 1950.

The Waterloo structure has about 100 feet of closure on top of the Ordovician Oneota Dolomite (fig. 11). Gas is stored in both the Oneota Dolomite and overlying New Richmond Sandstone of Ordovician age. The Waterloo oil pool was discovered in 1920, abandoned in 1930, revived in 1938, and converted to gas storage in 1951. About 238,000 barrels of oil were produced from limestone of the Kimmswick ("Trenton") Limestone at a depth of about 410 feet.

Gas for the Waterloo Project comes from a 22-inch pipeline of the Mississippi River Transmission Corporation by way of a 6-inch line. Since the reservoir is relatively small, it serves chiefly as a surge tank facility to compensate for diurnal demand variations on the line that supplies the St. Louis area. During the nights, when gas demands are lowest even in winter, gas is pumped into this facility to be withdrawn the following day if the demand calls for it. This is the only storage unit to be operated in this manner in Illinois at the present. The maximum amount of gas known to have been stored in the reservoir was 450 million cubic feet (MMcf) in 1959. As much as 21 MMcf has been withdrawn in one day. Current storage approaches 250 MMcf as higher pressures cause gas escape to overlying aquifers.

The underground storage of natural gas in Illinois is becoming increasingly important to our present-day society. As the population grows, greater amounts of gas are needed for home heating, cooking, and industrial use. Consumer demand for gas varies considerably from day to night as well as from summer to winter months because of fluctuating requirements, mainly for heating purposes. It would not be economically feasible or efficient to construct greater numbers of expensive pipelines

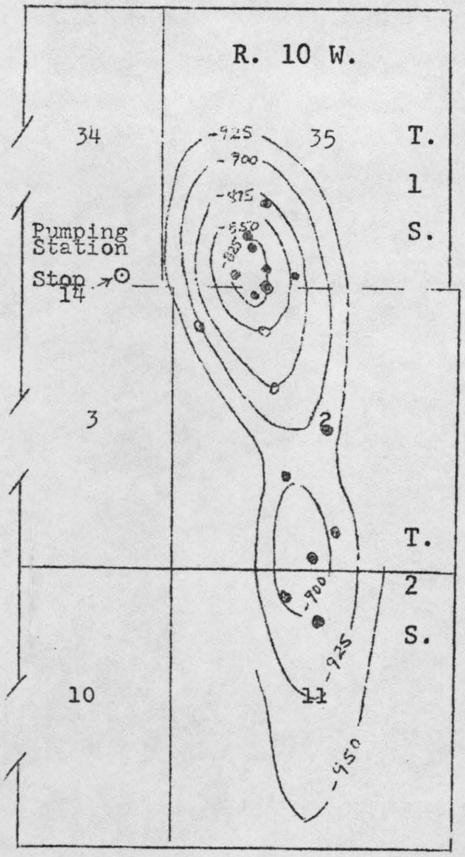


Fig. 11 - Structure contours on the top of the Oneota Dolomite at Waterloo. Contour interval 25 feet; injection-withdrawal wells are shown.

large enough to meet peak demands during the winter heating season. By operating presently existing pipelines at full capacity on a year-round basis, the excess gas transmitted from major southern gas fields can be pumped into large underground storage facilities during the off-heating months and stored until it is needed in large market areas such as St. Louis and Chicago. This is exactly what is being done in Illinois and other states. At the present time there are 28 approved gas storage structures and 30 reservoirs in Illinois being used to store more than 400 billion cubic feet of natural gas.

In Illinois, 10 underground gas storage facilities utilize former oil or gas producing reservoirs, but the remainder utilize bedrock traps in structures that originally contained no commercial quantities of oil and gas. In Illinois gas is stored underground in Paleozoic strata ranging in age from Cambrian to Pennsylvanian. Ninety percent of the present storage capacity is in Cambrian and Ordovician sandstones.

A successful gas storage facility must have a suitable geologic structure in which there are porous and permeable strata overlain by impermeable caprock to trap the gas. The gas is pumped under pressure into the voids in the rock, which may be the spaces between the sand grains in a sandstone, the openings between mineral particles in limestone or dolomite, fractures in the rock, and solution cavities. The pore or void space in typical reservoir rock makes up 15 to 25 percent of its total volume. The permeability of the rock is extremely important because the voids must be interconnecting so that the gas can easily pass into and out of the reservoir. As the gas is forced into the reservoir rock, it displaces some of the fluids that already occupy the voids and eventually forms a bubble. During withdrawal of the gas, the pressure within the storage bubble is reduced, and the water reoccupies the voids.

Leave Stop 14. Continue ahead.

0.6	38.5	Gas wellhead on right.
0.4	38.9	STOP. Turn right (south) on Route 3. CAUTION.
0.5	39.4	Note how even the upland is in this vicinity. The road follows the high ground along the axis of the anticline.
0.45	39.85	New Hanover Road on right. Prepare to turn left.
0.2	40.05	T-road from left. Turn left (east).
1.35	41.4	Sharp right.
0.1	41.5	Sharp left.
0.4	41.9	The upland here has no sinkholes because it is underlain by the thick, shaly Pennsylvanian strata.

0.55	42.45	T-road from left. Continue straight ahead.
0.25	42.7	Sharp right.
0.25	42.95	T-road from left. Turn left toward Wiehls Lake.
1.5	44.45	STOP. T-road. Turn left and descend hill. Cross narrow bridge.
0.1	44.55	Cross Prairie Du Long Creek.
0.95	45.5	T-road. Turn right.
0.25	45.75	Turn right.
0.25	46.0	Turn left.
0.6	46.6	Turn right.
0.5	47.1	SLOW. Bear right off blacktop onto gravel road.
0.4	47.5	Continue past houses.
0.15	47.65	Cross creek.
0.1	47.75	Traveled road ends.

Stop 15. Fossil collecting in limestones and shales of the Chesterian Paint Creek Group (SW 1/4 SW 1/4 SE 1/4, sec. 3, T. 2 S., R. 9 W.).

Shales and limestones of the Chesterian Paint Creek Group, seen earlier at Stop 12, are again exposed in the bank of Prairie du Long Creek. This exposure is one of several exposures that occur within windows eroded by streams in the overlying cover of Pennsylvanian strata east of the Pennsylvanian boundary (fig. 2). These windows are because of the relief on the pre-Pennsylvanian erosion surface.

The section here includes very fossiliferous, coarsely clastic, oolitic limestones and sandy fossiliferous shales. At the section just north of the bridge the exposed strata include from the creek: oolitic limestone (2'), green shale and thin interbedded limestones (10'), argillaceous, cross-bedded limestone (3'), red shale (1'), and sandstone (3'). The green shale is very fossiliferous and contains abundant well preserved Pentremites. Note how the upper limestone north of the bridge is channeled into the underlying shale.

Another excellent exposure occurs upstream to the west about 300 yards. There the characteristic red shale of the Paint Creek with thin limestones are predominant and are also rich in fossils. The extreme variability in the Chesterian strata is well-illustrated by these exposures. Assuming that these are the same intervals, it is impossible to correlate units between them, even within this short distance. It is possible that a fault passes between these two sections (see Itinerary Map). Immediately under the bridge, in the creek bottom, a large block of sandstone, overlain by limestone, is standing almost vertically. This fact strongly suggests the presence of a small fault, as shown on the Itinerary Map, and might explain why the two exposures are so different.

Pentremites are echinoderms that are related to the crinoids and the modern starfish. They belong to an extinct group of echinoderms known as blastoids. Starfish belong to the crawling group of echinoderms called eleutherozoa. The blastoids and crinoids were sessile animals that spent their adult lives anchored by a long segmented stem to one spot on the sea floor. They belong to the groups of echinoderms called pelmatozoa. The blastoids became extinct at the end of the Paleozoic Era about 200 million years ago, but their relatives, the crinoids, persist to this day. The Mississippian Period is often referred to as the age of the crinoids because of their great abundance in rocks of this age. Pentremites are very abundant in the Chesterian strata.

Whole crinoid calyces are rarely found as fossils because of their fragile skeletal structure. However, the heads or calyces of Pentremites are commonly well preserved because of their compact rugged structure. Although blastoids preferred a clear-water environment, they were apparently able to tolerate a fairly high degree of muddiness. They are often abundantly preserved in shales.

End of field trip.

We hope you had a good time!

Drive carefully!

FIELD TRIP PROPERTY OWNERS

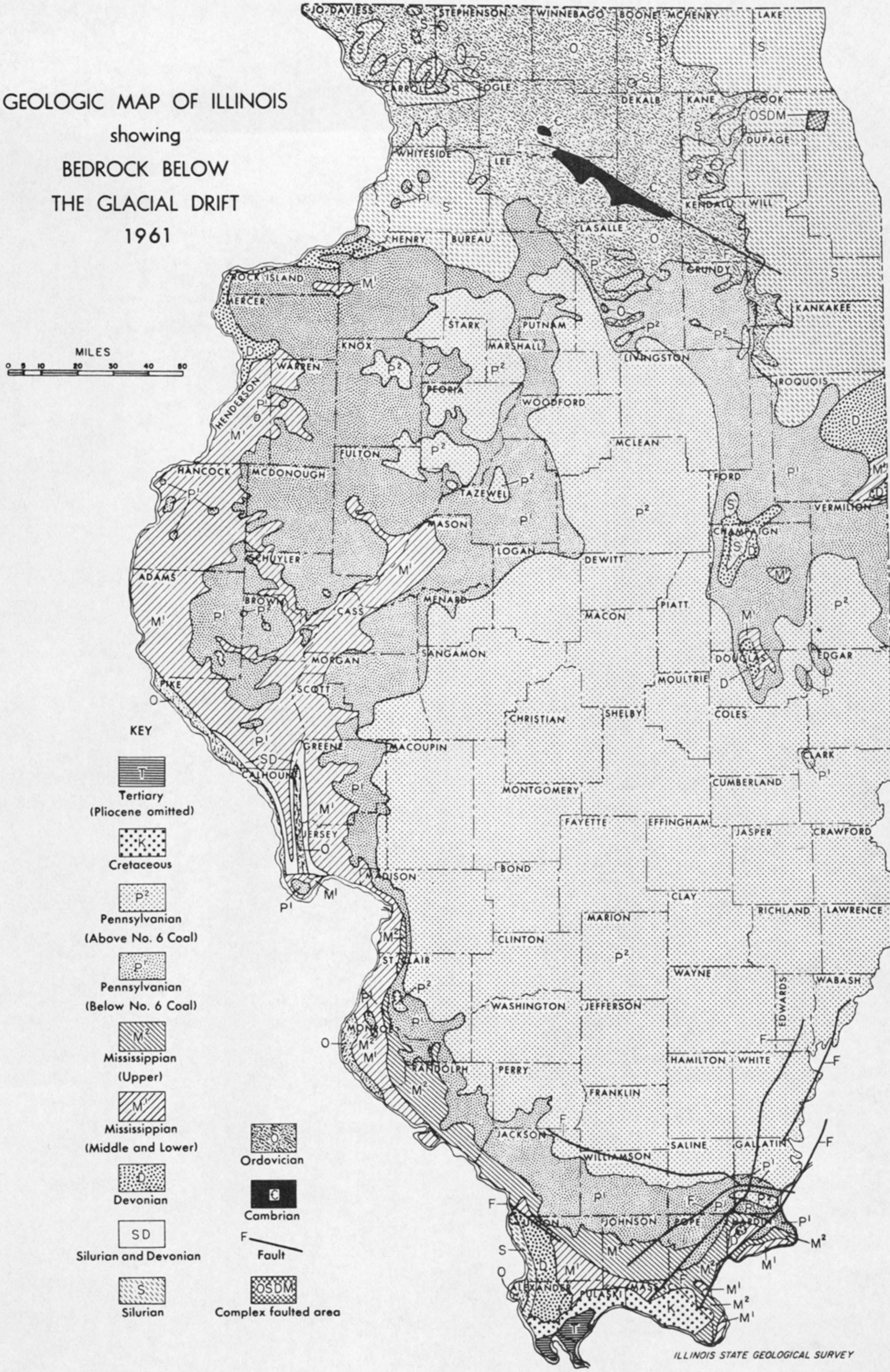
Stop	
3	Mr. Harvey Schmidt, Concordia Road, R. R. 3, Belleville, Illinois 62221 (First house south side of road west of Prairie Du Pont Creek Bridge).
	Mueller Nursery (Earl Mueller), 9101 Concordia Road, R. R. 3, Belleville, Illinois 62221 (First house north side of road west of Prairie Du Pont Creek bridge).
3-4	Part of field trip route passes through active quarry property operated by East St. Louis Stone Company, R. R. 1, Box 1605, East St. Louis, Illinois 62206.
4	Falling Springs Conservation Club, R. R. 1, Dupo, Illinois 62239.
5	Columbia Quarry Company, Dupo Plant, Dupo, Illinois 62239.
6	Mrs. Mamie Shondy, R. R. 1, East Carondolet, Illinois 62240 (Stone house on north side of road across from mines).
7	Mrs. Mildred Stupp, 510 Price Road, St. Louis, Missouri 63132.
	Dupo Oil Company (Charles R. Larson, Owner), Box 233, Dupo, Illinois 62239.
13	Mr. Clarence Gummersheimer, 814 South Rapp Street, Columbia, Illinois 62236.
	Mr. Emil Gummersheimer, 224 South Ferkle Street, Columbia, Illinois 62236.
14	Mississippi River Transmission Corporation, 9900 Clayton Road, St. Louis, Missouri 63124.
15	Mr. John Luckhardt, R. R. 3, Waterloo, Illinois 62298.

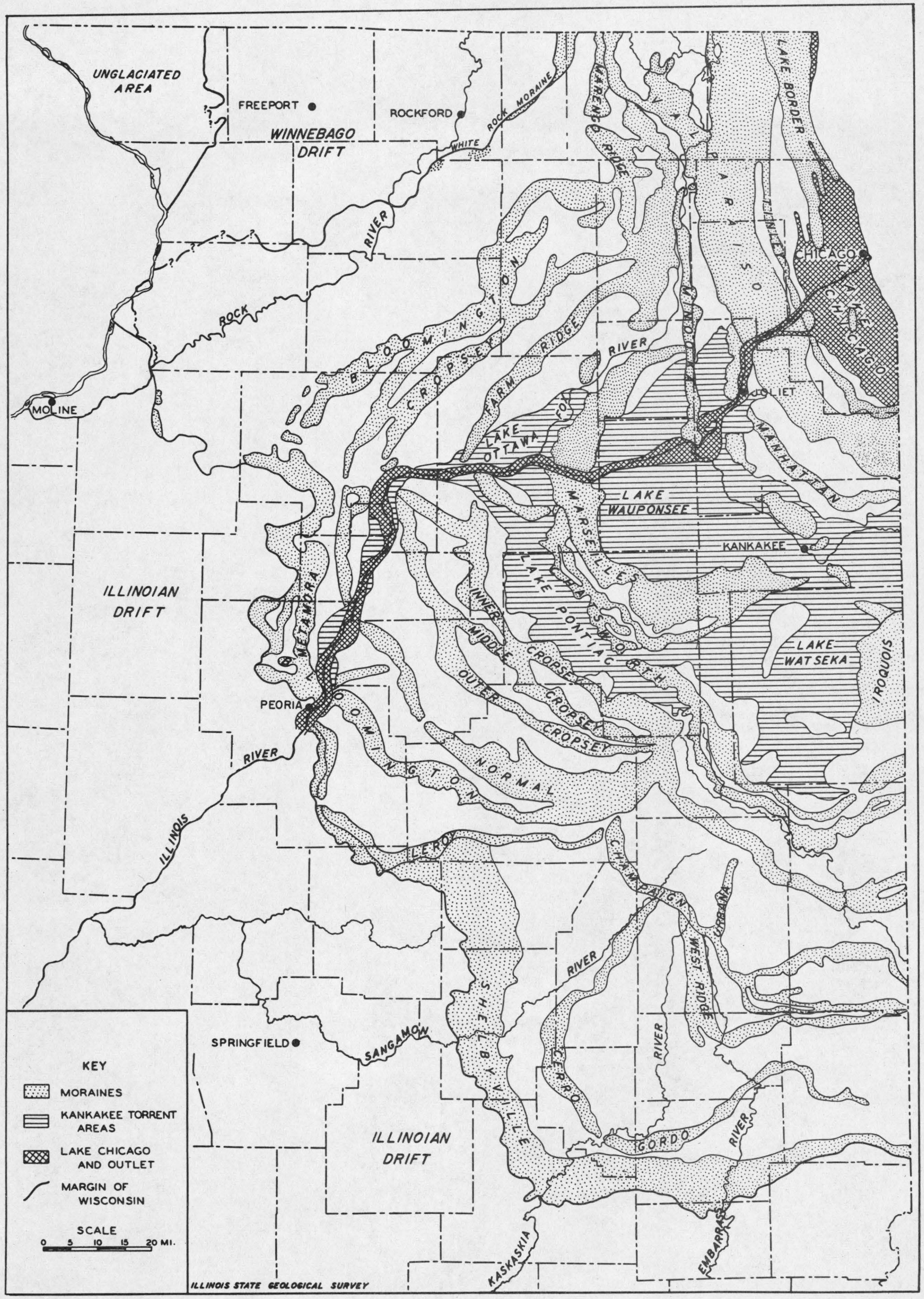
PHYSIOGRAPHIC DIVISIONS OF ILLINOIS

TIME TABLE OF PLEISTOCENE GLACIATION
(Illinois State Geological Survey, 1969)

STAGE	SUBSTAGE	NATURE OF DEPOSITS	SPECIAL FEATURES
RECENT	Years Before Present	Soil, youthful profile of weathering, lake and river deposits, dunes, peat	
	5,000		
WISCONSINAN (4th glacial)	Valderan	Outwash	Outwash along Mississippi Valley
	11,000		
	Twocreekan	Peat and alluvium	Ice withdrawal, erosion
	12,500		
	Woodfordian	Drift, loess, dunes, lake deposits	Glaciation, building of many moraines as far south as Shelbyville, extensive valley trains, outwash plains, and lakes
	22,000		
	Farmdalian	Soil, silt, and peat	Ice withdrawal, weathering, and erosion
	28,000		
	Altonian	Drift, loess	Glaciation in northern Illinois, valley trains along major rivers, Winnebago drift
	50,000 to 70,000		
SANGAMONIAN (3rd interglacial)		Soil, mature profile of weathering	
ILLINOIAN (3rd glacial)	Buffalo Hart	Drift	Glaciers from northeast at maximum reached Mississippi River and nearly to southern tip of Illinois
	Jacksonville	Drift	
	Liman	Drift, loess	
YARMOUTHIAN (2nd interglacial)		Soil, mature profile of weathering	
KANSAN (2nd glacial)		Drift Loess	Glaciers from northeast and northwest covered much of state
AFTONIAN (1st interglacial)		Soil, mature profile of weathering	
NEBRASKAN (1st glacial)		Drift	Glaciers from northwest invaded western Illinois

GEOLOGIC MAP OF ILLINOIS
showing
BEDROCK BELOW
THE GLACIAL DRIFT
1961



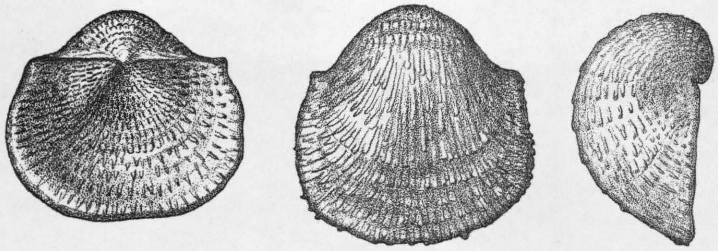


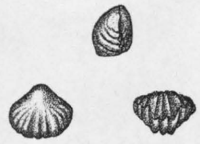
GLACIAL MAP OF NORTHEASTERN ILLINOIS

George Ekblaw

Revised 1960

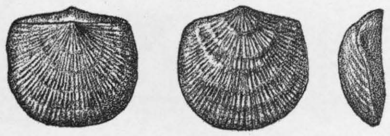
BRACHIOPODS



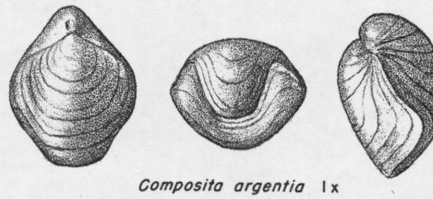


Wellerella tetrahedra 1½ x

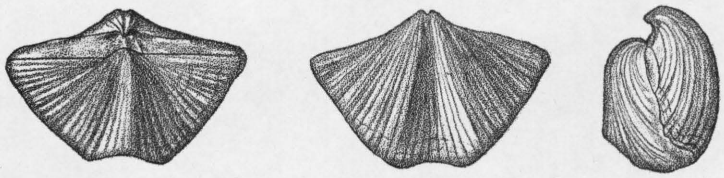
Juresania nebrascensis ⅔ x



Derbya crassa 1x



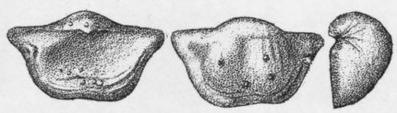
Composita argentia 1x



Neospirifer cameratus 1x

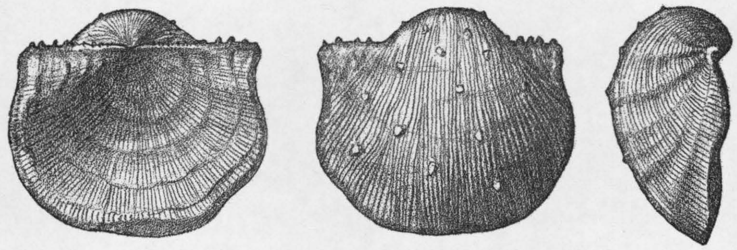
Chonetes granulifer 1½ x

Mesolobus mesolobus var. *evampygus* 2x

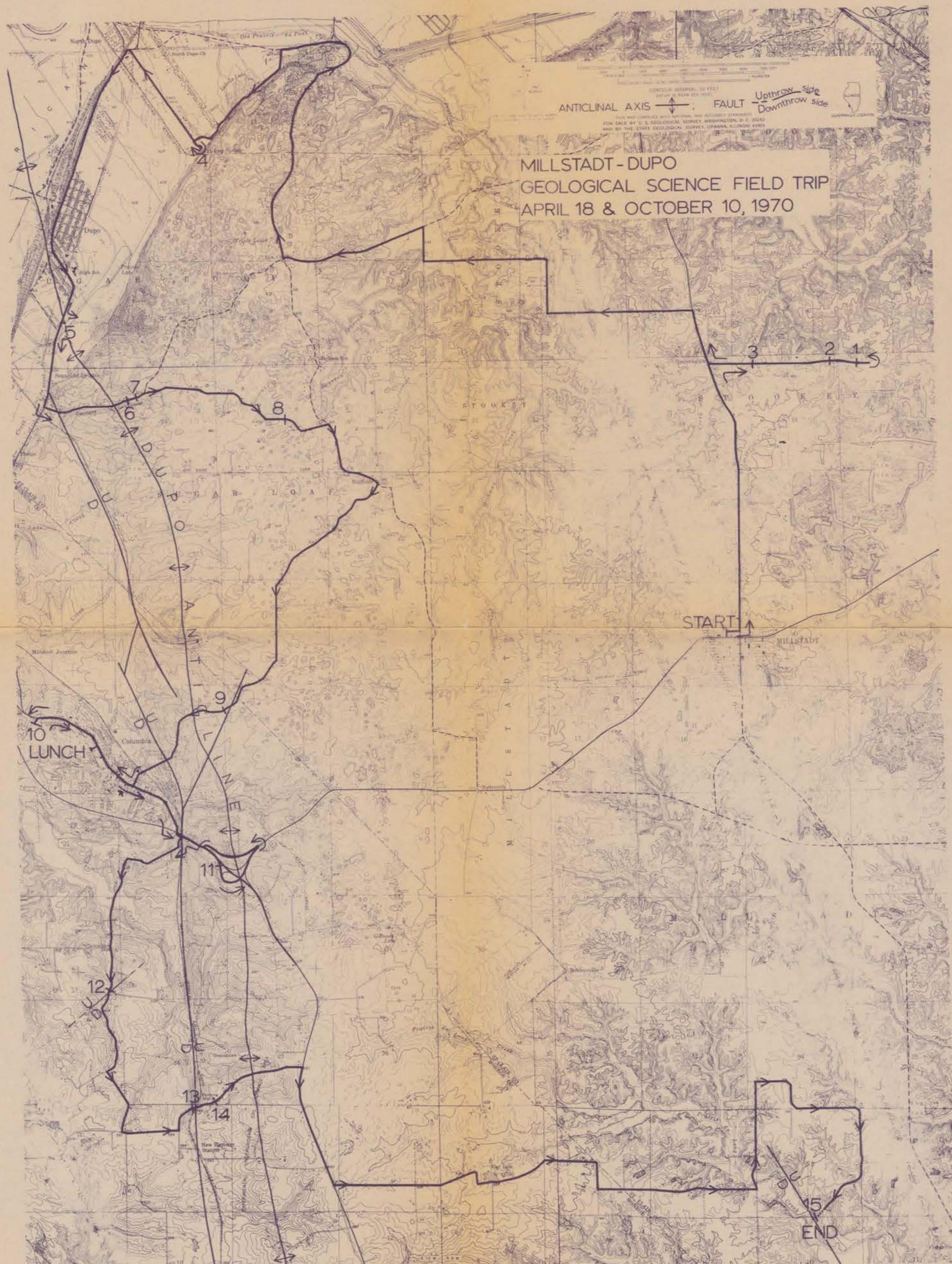


Marginifera splendens 1x

Crurithyris planoconvexa 2x



Linoproductus "cora" 1x



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